The Economics of Open-Access Journals

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Abstract: A new business model for scholarly journals, open access, has gained wide attention. An open-access journal's articles are available over the Internet free of charge to all readers; revenue to cover publication costs comes from authors' fees. We provide a theoretical analysis of open access in a model in which journals serve as intermediaries between authors and readers in a two-sided market. The key assumption is that traditional journals cannot commit to subscription fees when authors—who prefer wide readership induced by low subscription fees—make their submission decision. This leads to a "hold up" problem manifested as excessively high subscription fees. Open access is the only commitment device available to journals, a crude commitment not to charge readers at all. We compare the efficiency and profitability of traditional versus open-access journals under different market structures. We consider a variety of extensions including to non-profit journals, bundled journals, and hybrid journals (which offer authors the option to purchase open access for a premium).

Keywords: Open access, scholarly journal, two-sided market, competition

Journal of Economic Literature Codes: L14, L82, D40, L31

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1. Introduction

Traditional scholarly journals earns most of their revenue from fees charged to subscribers. Focus for the moment on library subscription fees since they constitute most of journal revenue, especially for journals published by for-profit firms. Library subscription fees vary widely across journals and can be quite high. Updating a study by Bergstrom (2001), Table 1 compares yearly library subscription fees for the top ten journals published by non-profit firms—which Bergstrom (2001) takes as a proxy for journal costs—to those published by for-profits.[1] The median for-profit subscription fee is $2,339, 4.4 times higher than the average non-profit fee. All but one of the ten for-profit journals have higher subscription fees than all of the ten non-profits.

Recent developments in the market for journals led to dissatisfaction among some scholars and librarians with the traditional business model.[2] The advent of the Internet offered the prospect of nearly zero marginal cost distribution of journals in electronic form, potentially much lower than the traditional method of mailing print copies. While such technological advances might be expected to result in lower journal prices, real journal prices continued to rise. In his sample of biomedical journals published by commercial firms, McCabe (2002) found average library subscription fees more than doubled from the 1988–1994 period to the 1995–2001 period.[3]

This dissatisfaction with the traditional business model for journals led to the proposal of an alternative: the open-access model. An open-access journal's articles are available over the Internet free of charge to all readers. Revenue to cover publication costs (and generate a profit for commercial publishers) comes from fees charged to submitting authors. Figure 1 documents the growth in numbers of open-access journals as listed on a leading clearinghouse, the Directory of Open Access Journals. Across all subject areas, about 650 journals were added on average each year, for a present total of 5,112. A regression with a quadratic trend term shows a statistically

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

[2] For journalistic accounts, see Weiss (2003) and Howard (2010), and for a policy analysis, see Willinsky (2006).

[3] Current price trends will be discussed below. McCabe (2002) provides evidence that the price increase was due in part to a wave of mergers among commercial publishers, which dramatically increased ownership concentration during that period. For example, the market share of the dominant firm, Elsevier, exceeded 50 percent in biomedical journals by some measures.

significant but modest acceleration in the trend, at the rate of about 30 journals per year.

Panel A of Figure 2 shows the breakdown of the 5,112 open-access journals by country. The largest share is headquartered in the United States (21%), followed by Brazil (9%) and the United Kingdom (8%). The distribution is fairly unconcentrated across countries, with over 100 headquartering at least one open-access journal. Panel B provides a breakdown by subject area. Biology and medicine account for 42% of open-access journals, followed by the social sciences (29%) and humanities (12%).

Returning to Figure 1, Panel B shows the entry of open-access journals in our own subject area, economics. On average, 13 new such journals were added per year for a total of 93 currently, accelerating at the statistically significant but modest rate of 0.7 journals per year. As Table 2 shows, most of these journals are relatively low-impact. Only the listed 12 have attained a measurable IDEAS/RePEc ranking (see the table notes for methodology), and of these only three have broken into the top 200. Given that the journals are relatively new, the impact will presumably grow over time for some of them.

There have been examples of the high-impact open-access journals in other subject areas. The most widely publicized initiative is the Public Library of Science (PLoS), publishing the *PLoS Biology*, *PLoS Medicine*, and *PLoS One* journals, founded by Nobel-prize-winning biologist Harold Varmus with a $9 million grant from the Moore Foundation. In 2009, *PLoS Biology* attained the highest impact factor among biology journals and *PLoS Medicine* the sixth highest among medical journals according to the Thomson Reuters Journal Citation Reports. *PLoS One*—a general science journal which aims to referee papers papers only on the basis of the rigor of the methodology, letting the "market" judge the importance of the results ex post—published nearly 7,000 articles in 2010, becoming the largest journal in the world (Morrison 2011). *PLoS Biology* and *PLoS Medicine* charge $2,900 and *PLoS One* $1,350 to authors of accepted papers.[4]

The fee structure of journals has potentially important consequences for social welfare. Sub-

[4] By contrast, open-access journals in economics charge much lower author fees. Of the three top-ranked journals in Table 2, only one, *Theoretical Economics*, charges author fees, a $75 submission fee, waived for members and reduced for authors from developing countries. Presumably these journals operate on grants and donations of labor and computer facilities.

scription prices rose to the point where libraries began to cancel significant titles (Weiss 2003, Howard 2010). These cancellations 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 at the margin.[5] Since journals are a channel for dissemination of knowledge in the economy, 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.

Many questions surround the economics of open-access journals. First, it is not obvious that profit-maximizing journals would ever voluntarily choose to have open access. If such examples exist, they may depend on special conditions on market structure, demand, and costs. Second, it is not obvious that a non-profit journal with the objective of introducing open access would be competitively viable. If open access only leads to a slight increase in readership and impact, authors may choose to stay with traditional journals and avoid the open-access journal's higher author fees. Third, it is not obvious that social welfare is enhanced by open access. True, it reduces any deadweight loss on the reader side. But if author fees need to be raised to pay for publication costs and to provide a profit margin, it may increase deadweight loss on the author side, leading to the publication of less research.

To address these and other related questions, in this paper we construct a simple model of journals as intermediaries in a two-sided market, intermediating between authors on one side and readers on the other. Each side of the market benefits from externalities provided by the other: an author benefit from additional readers because this increases his impact and citations; a reader

[5]The possibility that open access will offer more citations to authors is suggested by Lawrence's (2001) study of 1,500 computer conference "venues" that publish some of their content as open-access articles and some only in print. Within venues, open-access articles generated over three times the citations of print articles. Similarly huge effects of open access were found in other contexts by Antelman (2004) and Harnad and Brody (2004). None of these studies fully accounts for the possible non-random selection of articles for open access. Gaule and Maystre (2008) show that almost all of the measured increase in citations from open access is a selection bias, which disappears when one instruments for open access. Other recent attempts to control for this selection bias include Davis *et al.* (2008) and Gargouri *at al.* (2010).

benefits from additional articles because articles contain content which is valuable to readers.[6] Since authors are unable to compensate readers for these externalities and vice versa, how total fees are divided between authors and readers will matter in equilibrium because fees cannot simply be passed through.

The model, laid out in Section 2, hinges on a commitment assumption which we argue captures the key difference between traditional and open-access journals in practice and which turns out to deliver a wealth of interesting theoretical implications. 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 documented below that the average article receives most of its citations well after the the year of publication, whereas no traditional journal quotes subscription fees beyond the current year. This inability to commit means that a traditional journal has only one instrument to compete for authors: the submission fee. All other things equal, authors would prefer the journal to charge a low submission fee and thus attract 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. One crude commitment mechanism is available to a journal. While it cannot commit to a specific positive subscription fee, at the start of the game it can commit not to charge readers at all, thus becoming an open-access journal. The commitment involves a tradeoff for the journal: it is attractive to authors, especially those who value readership highly, and can boost profit earned from authors but it sacrifices all the profit earned from readers.

In Sections 3–5, we analyze the equilibrium in a variety of different market structures: monopoly traditional journal, monopoly open-access journal, and price competition among different combinations of them. A number of interesting findings emerge from the analysis. Subscription fees for traditional journals are high in a strong sense—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

[6] Empirical papers measuring externalities across two-sided media markets include Rysman's (2004) study of yellow pages, Kaiser and Wright's (2006) study of magazines, and Wilbur's (2008) study of television broadcasts. See Rysman (2009) for a review of the literature.

ante. The journal-author transaction suffers from a classical hold-up problem (Grout 1984). Still equilibrium with an open-access journal is not guaranteed to generate higher social welfare. In general an open-access journal charges a higher submission fee than a traditional journal, which for some parameters is more distortionary than a high subscription fee.

The model provides the logic for a paradoxical result that competing traditional journals may remain quite profitable despite offering products which are perfect substitutes (from an ex ante perspective, different journals are just different names applied to a given collection of articles). 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. Competition among open-access journals is in a sense 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. The non-negativity constraint on submission fees does not bind for open-access journals because they hit the non-negativity constraint on profits first. Thus there is a natural asymmetry in the competitiveness of traditional and open-access journals.

If a single open-access journal competes against a single traditional one, both can earn profit. The market resembles Shaked and Sutton's (1982) model of vertical differentiation. Here the traditional journal functions as the low-quality product because it provides authors with a narrower readership; the open-access journal provides them with wider readership and thus higher quality. Authors who place a high value on wide readership submit to the open-access journal, paying a higher submission fee; and lower-value authors submit to the traditional journal.

The model is amenable to a variety of extensions of practical relevance. Section 6 extends the analysis to non-profit journals. Section 7 allows journals to adopt a hybrid pricing model, whereby a traditional journal offers open access to the subset of articles for which the authors choose to pay a premium. This is an important case to analyze because the largest commercial publishers are starting to experiment with such a policy, and it is useful to understand its consequences for the market. Section 8 considers alternative assumptions about costs of serving readers. In an Internet era in which delivering articles to readers is virtually costless, the main source of reader costs is involved in administering their accounts. Open-access journals have no reader accounts to process and thus may face a lower reader cost than traditional journals. Traditional journals can combat this disadvantage by bundling journals, dividing any fixed administrative costs over the large number of journals included in the bundle. This extension provides a logic for bundling journals which has asymmetric across traditional and open-access journals.

Our paper is most closely related to the three other papers (McCabe and Snyder 2005, 2007; Jeon and Rochet 2010) that analyze the market for academic journals using two-sided-market models.[7] The main difference is in the underlying models. The present paper introduces novel assumptions about the timing of price setting and commitment that capture what we think is the key difference between traditional and open-access journals that is new in the literature. There are other differences as well. McCabe and Snyder (2005, 2007) are chiefly concerned with article and journal quality, requiring significant compromises to maintain the tractability of the analysis. McCabe and Snyder (2005) effectively transforms the two-sided-market model into a one-sided market one by assuming inelastic author demand. The short paper only provides a few results and only for a monopoly journal. McCabe and Snyder (2007) allow for one form of competition, that arising in a free-entry equilibrium, but to simplify the analysis they assume per-article prices for readers and per-reader prices for authors. Not only is this assumption counterfactual—submission and subscription fees are in fact lump-sum—allowing authors' total payment to increase with the number of readers effectively solves the hold-up problem between journals and authors that is the substance of the present paper. Solving for equilibrium in the more difficult case of lump-sum prices is a methodological contribution of the present paper. Jeon and Rochet (2010) make a number of simplifications, restricting attention to the monopoly case, abstracting away from

[7] Several other papers (McCabe 2004, Jeon and Menicucci 2006, Armstrong 2009) provided theoretical analyses of the market for academic journals using a one-sided-market model, which is not amenable to analyzing open-access questions.

reader costs, and assuming journals cannot charge both positive author and reader prices. Our model generalizes all of these dimensions.

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.[8] The papers in this literature closest to the present one are Armstrong (2006) and Rochet and Tirole (2006). These papers provide general analyses of platform competition for a variety of different cases. Each has a section on 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). Again, our model is fundamentally different, involving new assumptions about the timing of price setting and commitment. Our work differs in other details from Armstrong (2006) in that our specification of costs is more general and our platforms (journals) are homogeneous rather than being differentiated on a Hotelling line. Imperfect competition arises from a different source in our paper than horizontal differentiation. Much of the formal analysis in Rochet and Tirole (2006) is directed to the monopoly case. The Lerner-index formulas we derive in the monopoly case are qualitatively similar to theirs. Their analysis of platform competition is less formal, focusing on general principles such as how moving from monopoly to competition or from single to multihoming affects relative prices. Neither Rochet and Tirole (2006) nor Armstrong (2006) analyze open access, the central issue in our paper.

2. Model

The model has three types of economic agents: authors, readers, and journals. The representative author writes a single article. Each time his or her article is read, the author obtains benefit v^a, embodying the pure psychic benefit from being read as well as the benefit of having the journal

[8] The literature on two-sided markets includes Ambrus and Argenziano (2009); Armstrong (2006); Baye and Morgan (2001); Caillaud and Jullien (2001, 2003); Evans (2003); Hagiu (2006), Hermalin and Katz (2004); Jeon, Laffont, and Tirole (2004); Laffont *et al.* (2001); Rochet and Tirole (2002, 2003, 2006); Schmalensee (2002); and Wright (2004a, 2004b). For theoretical work on media markets, see Anderson and Coate (2005).

certify the quality of the article. Journal certification improves the author's chances of tenure, promotion, outside offers, and other career prospects. The certification benefit is here taken to be proportional to the number of readers since publication in a widely-read journal generates more cites and other measures of impact. On the other side of the market, a representative reader obtains benefit v^r from each article read. An individual's value v^i, $i \in \{a, r\}$, is a random variables having cumulative distribution function F^i and density function f^i on support $[0, \bar{v}^i]$. The upper bound on the support, $\bar{v}^i$, can be infinite; but the mean value, $E(v^i)$, is finite. The distribution of v^i is common knowledge, but the specific value is private information for the individual.

Journals serve as intermediaries between authors and readers. Processing an article costs the journal c^a, reflecting the effort involved in refereeing, copy editing, and typesetting—so-called "first copy" costs. Distributing an article to a reader costs c^r, reflecting printing and shipping costs as well as the cost of servicing the reader's account. In the case Internet rather than print distribution, printing and shipping costs are essentially zero, so servicing the reader's account is the only significant component of c^r. While journals a range of fields and quality levels, we will focus on a particular segment of the market within which all journals are assumed to be homogeneous.

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 makes academic journals a classic example of what the economic literature refers to as a two-sided market. See Rochet and Tirole (2006) for a discussion and review of the literature. 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.

In the basic model, journals are assumed to be profit maximizers. Journal j charges submission fee p^a_j and subscription fee p^r_j. Following industry practice, these fees are taken to be fixed. For example, p^a_j is not conditioned on the number of subscribers the journal ends up having. Since all articles are of equal quality, it makes no difference whether p^a_j is taken to be a submission fee or a publication fee since all submitted articles are accepted for publication in equilibrium. Also following industry practice, we constrain $p_j^a, p_j^r \geq 0$. Journals may subsidize authors and readers in setting prices below marginal cost, but journals cannot make explicit cash transfers to authors or readers.[9]

The model has four stages. In the first stage, journals compete for authors by setting p_j^a. In the second stage, authors make their submission decision. In the third stage, journals compete for readers by setting p_j^r. In the last stage, readers make their subscription decisions. We will solve for the subgame perfect equilibrium of this sequential game.

Different types of journal differ in their ability to commit to prices it will set in later stages. Traditional journals cannot commit in the first stage to the reader price it will set in the fourth stage. Contractual incompleteness prevents future subscription fees from being part of the contract journals sign 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 only available commitment mechanism for journals. Traditional journals, which reserve the right to charge positive reader fees, cannot commit to the exact level this positive fee takes.

Figure 3 offers evidence supporting the notion that traditional journals have difficulty committing to subscription prices. If an article received most of its cites in the of publication, then the author might just be concerned with the current number of readers, a function of the current subscription fee. In fact the bulk of cites come many years after publication. The figure reports an estimate of the survivorship function for cites for economics journal volumes. Over 95% of cites come more than a year after publication; nearly 80% come more than five years after publication. We are aware no traditional journal that has committed to a subscription fees beyond the current year, to say nothing of five years and beyond. If subscription fees were stable over time, the current fee might provide some assurance about future levels. However, McCabe (2002) found annual subscription-fee increases averaging around 10% during the period studied. Further

[9]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.

reducing commitment ability, large commercial publishers negotiate with individual institutions over subscription prices for their bundle of journals (see, e.g., McCabe 2004), so the published subscription price is now more of a list price which few subscribers pay.

Two features of the model deserve to be highlighted as the solutions to the puzzle of how journals can be homogeneous but at the same time imperfectly competitive: namely, journals cannot offer negative submission fees and traditional journals cannot commit to submission fees. If journals could offer negative subscription fees, competition for authors would dissipate all rents through that channel. Even with the floor on submission fees, if journals could commit to subscription fees, they could compete for authors indirectly through reductions in subscription fees (which are attractive to authors via increased readership). The inability to commit to subscription fees prevents journals from dissipating all rents through competition in that dimension. Thus some rents are preserved in spite of the homogeneity of journals.

Let T be the set of traditional journals and O the set of open access journals entering the market. We will take the numbers of each type, $|T|$ and $|O|$, to be exogenous and examine equilibrium for all whole-number combinations $(|T|,|O|)$. Section 4 analyzes the case of a monopoly journal, taking each subcase of a traditional and an open-access journal in turn. Section 5 analyzes the case of competing journals, first analyzing competition among just traditional journals, then among just open-access journals, then among a combination of both types. Before solving for equilibrium in these cases, we characterize the first-best benchmark.

3. First Best

The social welfare generated by arbitrary author price p^a and reader price p^r equals the expected value of the net surplus of the representative author and reader at these prices less the cost of serving them:

$$SW_(p^a, p^r) = \int_{p^a/Q^r(p^r)}^{\bar{v}^a} \left[Q^r(p^r)v^a - c^a + \int_{p^r}^{\bar{v}^r} (v^r - c^r)dF^r(v^r) \right] dF^a(v^a), \tag{1}$$

or, after manipulating,

$$SW_(p^a, p^r) = \int_{p^a/Q^r(p^r)}^{\bar{v}^a} \left[\int_{p^r}^{\bar{v}^r} (v^a + v^r - c^r) dF^r(v^r) - c^a \right] dF^a(v^a). \tag{2}$$

Taking the first-order conditions with respect to prices and rearranging gives the following expressions for the first best.

Proposition 1. *The first-best submission and subscription fees are*

$$\begin{aligned} p^a_{fb} &= \max\left\{0, c^a - E(v^r - c^r | v^r > p^r_{fb}) \Pr(v^r > p^r_{fb})\right\} \\ p^r_{fb} &= \max\left\{0, c^r - E(v^a | v^a > p^a_{fb}/Q^r(p^r_{fb}))\right\}. \end{aligned}$$

A formal proof is provided in Appendix A. Note that implicit in the expressions for first-best prices is the requirement that they respect the non-negativity constraint on prices.

The first-best prices have an intuitive structure. They are set to the cost of serving the side of the market in question, adjusted downward by a term reflecting the net social benefit coming from the other side of the market.

Consider a digital environment in which there is no cost of serving readers under open access, i.e., $c^r = 0$. Then an immediate corollary of Proposition 1 is that the first best involves open access: i.e., $p^r_{fb} = 0$. This corollary is our first suggestion of possible efficiencies associated with open access. This corollary does not imply, however, that equilibrium with a profit-maximizing open-access journal is socially efficient. In general, such a journal would distort the submission fees above author cost to provide a profit margin. Nor does this corollary imply that equilibrium social welfare is higher with open-access than traditional journals. We move from an analysis of socially efficient outcomes to equilibrium outcomes next.

4. Monopoly Journals

This section solves the equilibrium with a monopoly journal. Section 4.1 solves for equilibrium with a monopoly traditional journal and Section 4.2 with a monopoly open-access journal.

4.1. Monopoly Traditional Journal

We use backward induction to solve for equilibrium starting with the representative reader's subscription decision in the last stage. The reader only subscribes to a journal that has published an article. In that case, the reader's net surplus is $v^r - p^r$. He strictly prefers to subscribe if $v^r > p^r$. Letting $Q^r(y) \equiv 1 - F^r(y)$, the probability the reader subscribes, and thus the journal's expected number of readers, is $Q^r(p^r)$.

Folding the game back to the third stage, if the journal has an article, it chooses p^r to maximize the expected continuation profit from the reader:

$$p^r_{mt} \equiv \underset{p^r \geq 0}{\operatorname{argmax}} (p^r - c^r) Q^r(p^r). \tag{3}$$

The subscript on the optimal price identifies the journal as traditional and the market structure as monopoly.

This is a standard monopoly pricing problem. Rearranging the first-order condition from maximizing (3) yields the Lerner index formula

$$L^r_{mt} \equiv \frac{p^r_{mt} - c^r}{p^r_{mt}} = \frac{1}{|\eta^r_{mt}|}, \tag{4}$$

where η^r_{mt} is the elasticity of reader demand evaluated at the equilibrium subscription price, i.e.,

$$\eta^r_{mt} \equiv Q^{r\prime}(p^r_{mt}) \frac{p^r_{mt}}{q^r_{mt}}, \tag{5}$$

and where $q^r_{mt} \equiv Q^r(p^r_{mt})$ denote the expected number of readers in equilibrium. Equation (4) is the standard inverse elasticity rule for monopoly markups.

Folding the game back to the second stage, the representative author obtains net surplus $v^a q^r_{mt} - p^a$ from submitting a paper, the benefit per reader v^a times the equilibrium number of readers q^r_{mt} less the submission fee p^a. The author submits if $v^a > p^a / q^r_{mt}$. Letting $Q^a(y,z) \equiv 1 - F^a(y/z)$, the probability the author submits, also the expected number of articles in the journal, is $Q^a(p^a, q^r_{mt})$.

Folding the game back to the first stage, the journal chooses p^a to maximize profit from all stages:

$$p^a_{mt} \equiv \underset{p^a \geq 0}{\text{argmax}} (p^a - c^a + \pi^r_{mt}) Q^a(p^a, q^r_{mt}). \tag{6}$$

The term $\pi^r_{mt} \equiv (p^r_{mt} - c^r) q^r_{mt}$ reflects the expected continuation profit from readers attracted by the article. Rearranging the first-order condition from maximizing (6) yields the Lerner index formula

$$L^a_{mt} \equiv \frac{p^a_{mt} - c^a}{p^a_{mt}} = \frac{1}{|\eta^a_{mt}|} - \frac{\pi^r_{mt}}{p^a_{mt}}. \tag{7}$$

where η^a_{mt} is the elasticity of author demand evaluated at the equilibrium submission fee, i.e.,

$$\eta^a_{mt} \equiv Q^a_1(p^a_{mt}, q^r_{mt}) \frac{p^a_{mt}}{q^a_{mt}}, \tag{8}$$

and where $q^a_{mt} \equiv Q^a(p^a_{mt}, q^r_{mt})$.

This Lerner index formula in (7) holds for an interior solution ($p^a_{mt} > 0$) to (6). Otherwise we simply have the corner solution $p^a_{mt} = 0$.[10] The Lerner index characterizing the author price in (7) is lower than the standard inverse elasticity rule for a monopolist by the term π^r_{mt}/p^a_{mt}, 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., $p^a_{mt} < c^a$).

The following proposition summarizes the analysis of a monopoly traditional journal.

Proposition 2. *A monopoly traditional journal's submission fee p^a_{mt} satisfies the Lerner index condition $L^a_{mt} = (1/|\eta^a_{mt}|) - (\pi^r_{mt}/p^a_{mt})$ if $p^a_{mt} > 0$; otherwise $p^a_{mt} = 0$. Its subscription fee is positive ($p^r_{mt} > 0$), with associated Lerner index satisfying an inverse elasticity rule: $L^r_{mt} = 1/|\eta^r_{mt}|$.*

4.2. Monopoly Open-Access Journal

Next we turn to the case of a monopoly open-access journal, which commits ex ante to charge zero subscription fees ex post. We again solve for equilibrium using backward induction. The

[10] The solution will be interior if profit from the reader side is not so large as to overwhelm the incentive to extract revenue from authors: $\pi^r_{mt} < c^a$ is a sufficient condition. Another sufficient condition for an interior solution is $f^a(0) = 0$.

representative reader ends up subscribing to the free journal carrying an article. Folding the game back to the second stage, the representative author obtains net surplus $v^a - p^a$ from submitting a paper because the article certainly gains a reader. The author submits if $v^a > p^a$. The probability that the author submits, also the expected quantity of articles in the journal, therefore is $Q^a(p^a, 1) = 1 - F^a(p^a)$.

Folding the game back to the first stage, the journal chooses p^a to maximize total profit from all stages:

$$p^a_{mo} \equiv \underset{p^a \geq 0}{\operatorname{argmax}}[p^a - (c^a + c^r)]Q^a(p^a, 1). \tag{9}$$

The expression reflects the cost of serving the reader as well as the author but no revenue from readers. Rearranging the first-order condition from maximizing (9) yields the Lerner index formula

$$L^a_{mo} \equiv \frac{p^a_{mo} - c^a}{p^a_{mo}} = \frac{1}{|\eta^a_{mo}|} + \frac{c^r}{p^a_{mo}}. \tag{10}$$

where η^a_{mo} is the elasticity of author demand evaluated at the equilibrium submission fee, i.e.,

$$\eta^a_{mo} \equiv Q^a_1(p^a_{mo}, 1)\frac{p^a_{mo}}{q^a_{mo}}, \tag{11}$$

and where $q^a_{mo} \equiv Q^a(p^a_{mo}, 1)$.

Equation (10) 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. A profitable open-access journal will necessarily have positive author margins: i.e., $p^a_{mo} > c^a$; moreover $p^a_{mo} > c^a + c^r$.

The following proposition summarizes the analysis of a monopoly open-access journal.

Proposition 3. *A monopoly open-access journal charges no subscription fee $p^a_{mo} = 0$. Its submission fee is positive ($p^a_{mo} > 0$), satisfying Lerner index condition $L^a_{mo} = (1/|\eta^a_{mo}|) + (c^r/p^a_{mo})$.*

4.3. Comparing Monopoly Journals

Next we turn to a comparison of traditional versus open-access journal, holding constant the monopoly structure in both cases. We will compare prices, profits, and social welfare across the two types of journal.

Obviously, the equilibrium subscription fee is weakly lower for an open-access than for a traditional journal. Under open access, the subscription fee is the lowest possible non-negative price, 0. Regarding submission fees, a comparison of the Lerner index formulae (7) with (10) suggests that the submission fee will be higher for the open-access than the traditional journal because the markup is above the inverse elasticity for the open-access journal but below for the traditional journal. Still, it is difficult to unambiguously rank the submission fees because the elasticities in the formulae are difficult to rank. The following proposition, proved in Appendix A, shows that a standard monotone hazard rate condition is sufficient for the open-access journal to charge a higher price than the traditional journal.

Proposition 4. *A monopoly open-access journal has a weakly lower subscription fee than a monopoly traditional journal:* $p^r_{mo} = 0 \leq p^r_{mt}$*. Assume that the distribution of author benefits has a nondecreasing hazard rate and that a monopoly journal of either type makes strictly positive profit. Then the open-access journal has a strictly higher submission fee than the traditional journal:* $p^a_{mo} > p^a_{mt}$*.*

Turning from a comparison of prices to profits, we will show in Proposition 5 that there are conditions under which an open-access journal is more profitable than a traditional journal and other conditions under which the opposite is true. At first glance one might think that the commitment to a low (indeed zero) price involved in open access may reduce profit. However, if the author side of the market is a substantial enough source of revenue relative to the reader side, the commitment to zero subscription fee and thus the widest possible readership associated with open access may boost the revenue from the author side enough to outweigh the profit sacrificed from the reader side. Conversely, if the reader side grows in importance as a revenue source, the traditional journal eventually becomes more profitable because it profits from the reader side, while the open-access journal does not. These insights are stated formally in the following proposition, proved in Appendix A.

Proposition 5. *Scaling the author benefit as $\theta^a v^a$ while holding all other parameters constant, a monopoly open-access journal is more profitable than a traditional one for sufficiently high θ^a. Scaling the reader benefit as $\theta^r v^r$ while holding all other parameters constant, a monopoly traditional journal is more profitable than an open-access one for sufficiently high θ^r.*

Endogenizing the journal's pricing policy, Proposition 5 implies that a monopoly journal would choose open access for a sufficiently high distribution of author values *ceteris paribus* and would choose traditional pricing for a sufficiently high distribution of reader values *ceteris paribus*.

Rather than taking the limit as the value on one side of the market increases, we can obtain a similar result in the limit as the value on the other side shrinks. The result is less clean because additional conditions on the parameters are needed. We still state and prove the result because it will be useful for a subsequent proposition.

Proposition 6. *Scaling the reader benefit as $\theta^r v^r$ while holding all other parameters constant, if $\bar{v}^a > c^a + c^r$, then a monopoly open-access journal is more profitable than a traditional one for θ^r sufficiently close to 0. Scaling the author benefit as $\theta^a v^a$ while holding all other parameters constant, if $0 < c^a < \pi^r_{mt}$, then a monopoly traditional journal is more profitable than an open-access one for θ^a sufficiently close to 0.*

The proof is provided in Appendix A.

To illustrate Propositions 5 and 6, consider a numerical example with $c^a = 1/4$, $c^r = 0$, v^a uniformly distributed on $[0, \bar{v}^a]$, and v^r uniformly distributed on $[0, \bar{v}^r]$. It can be shown that a monopoly journal would choose open access if $\bar{v}^a > 1.2\bar{v}^r - 0.7$ (rounded to the nearest decimal) and traditional pricing otherwise.

Turning to a welfare comparison between traditional and open-access pricing, the picture is again inconclusive. Neither regime is unambiguously more efficient than the other. Equilibrium sometimes selects traditional pricing when it is socially inefficient and sometimes open access when it is socially inefficient. This possibility result is best illustrated with a concrete numerical example, shown in Figure 4, the same numerical example from the previous paragraph. All four possibilities arise in the figure. Holding constant the distribution of reader benefits, if the distribution of author benefits is enlarged, open access becomes efficient and is selected in equilibrium.

The opposite happens if author benefits are held constant and the distribution of reader benefits is enlarged: traditional access is efficient and is selected in equilibrium. Equilibrium selects an inefficient pricing model when the distributions of author and reader benefits are more similar, with open access being inefficiently selected for smaller benefit distributions and with traditional access inefficiently selected for larger distributions.

The conditions under which equilibrium selects the efficient pricing model generalize beyond the figure, as stated in the following proposition, proved in Appendix A.

Proposition 7. *Scaling the author benefit as $\theta^a v^a$ while holding all other parameters constant, a monopoly open-access journal is more profitable and more socially efficient than a traditional one for sufficiently high θ^a. If $0 < c^a < \pi^r_{mt}$, then a monopoly traditional journal is more profitable and more socially efficient than an open-access one for θ^a sufficiently close to* 0*.*

Intuitively, if author values grow without bound, the journal earns all its profit from authors, so the gain from committing via open access to a low reader price exceeds the loss from the fact that the commitment is a crude one to a zero price. Indeed, the loss is vanishingly small because committing to free reader access is optimal in this limit. If author values shrink to zero, then journals only source of profit is readers, and only traditional access exploits this profit source. Hence traditional access is more profitable in this limit. All social surplus also comes from reader side in this limit. Traditional access involves a lower author markup than open-access, leading to more submissions, and indirectly to more surplus on the reader side. Hence traditional access is socially more efficient in this limit as well.

5. Competing Journals

In this section we move from an analysis of monopoly to competing journals. Section 5.1 analyzes competition among two or more traditional journals, Section 5.2 among two or more open-access journals, and Section 5.3 among a set of journals including at least one of each type.

5.1. Competing Traditional Journals

Suppose there are $|T| \geq 2$ traditional journals in the market and no open-access journals. Using backward induction to solve for equilibrium, the continuation equilibrium in the last two subscription stages is identical to that for 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. The author's submission strategy is also the same as in the previous section.

Competition for authors in the first stage drives p^a_{ct} all the way down to the zero-profit level unless this violates the constraint $p^a_{ct} \geq 0$, in which case $p^a_{ct} = 0$. As shown in the proof of the next proposition, the zero-profit submission fee equals $c^a - \pi^r_{mt}$. Putting these facts together, $p^a_{ct} = \max(0, c^a - \pi^r_{mt})$, that is, the equilibrium submission fee is either a zero-profit or zero-price one, whichever is greater.

Proposition 8. *Competition among $|T| \geq 2$ traditional journals leads to submission fee $p^a_{ct} = \max(0, c^a - \pi^r_{mt})$. The equilibrium subscription fee is the same as for a monopoly traditional journal: $p^r_{ct} = p^r_{mt}$.*

Proposition 8 allows us to make inferences about the profitability of competing traditional journals from submission fees. If $p^a_{ct} > 0$, then zero profits rather than zero prices must be the binding constraint. Hence journals must be earning zero profits in this market. Paradoxically, free submission is a necessary condition for competing traditional journals to earn positive profit. Except for the knife-edged case in which $c^a = \pi^r_{mt}$, free submission is also a sufficient condition for positive profits in this market.

To emphasize, the journals market is a case in which competition among identical suppliers does not inevitably lead to zero profits. Competing traditional journals earn positive profit if and only if $c^a \neq \pi^r_{mt}$ and $p^a_{ct} = 0$. In this case the journals are profitable in spite of the fact that they are competing suppliers of identical products. Once the journal has articles, it becomes a monopoly provider access to those articles, allowing positive continuation profit. First-stage competition for articles may not necessarily dissipate this continuation profit completely if negative author fees would be required to do so.

Comparing Propositions 2 to 8, we can assess the comparative-static effect of the entry of a traditional journal into a market with an existing monopoly one. Such entry has no effect on the subscription fee. The only effect is a (weak) reduction in the submission fee. Profits fall (weakly) but not necessarily to zero. Since Proposition 8 holds for any $|T| \geq 2$, we can see that once the second journal has entered, further entry has no effect on prices or market-wide profit. Per-journal profit would fall as the set market-wide expected profit is divided among more journals. We have not modeled a sunk entry cost; but if such a cost were added to the model, it could be used to compute a bound the maximum number of journals that would endogenously enter the market.

Considering the for-profit journals listed in Table 1, half of them charge no submission fee, and the median is $25. This is a greater rate of free submission and a lower median submission fee than for the non-profit journals in the table. If we are willing to assume that the journals in the table face competition within their niche, the theory in this section would offer a partial explanation for the observed submission fees. The for-profit journals compete aggressively for articles with low submission fees. Journals charging zero submission fees would be the ones predicted to be earning positive profits. Of course observed submission fees may serve practical purposes outside of the model such as providing a barrier to low-quality submissions (there is no role for such a barrier in the model because it abstracts from such quality considerations).

5.2. Competing Open-Access Journals

Next suppose there are $|O| \geq 2$ open-access journals in the market and no traditional ones. To solve for the equilibrium submission fee, we can use the same "Bertrand" logic as in the previous section. Competition among the journals drives p^a_{co} down to the zero-profit level, which can be shown to be $p^a_{co} = c^a + c^r$. A simplifying factor here is that costs are non-negative, so this fee is guaranteed to satisfy the zero-price constraint.

Proposition 9. *Competition among $|O| \geq 2$ open-access journals leads to submission fee $p^a_{co} = c^a + c^r$. By definition they charge no subscription fee $p^a_{co} = 0$.*

Even in a digital environment in which $c^r = 0$, the submission fee is still positive as long as $c^a > 0$.

5.3. Competition Among Both Types

This section analyzes competition with both traditional and open-access journals in the market. We begin with the case of exactly one of each in the market, i.e., $|T| = |O| = 1$. Other market structures with different numbers of these types can be derived as corollaries of this analysis.

The subscription stage is identical to what we have found before. If the traditional journal attracts the article, it monopolizes this vis-a-vis readers; the open-access journal of course posts the article for free. The remaining question regards the equilibrium submission fees arising from competition. 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 is 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 5 provides a schematic diagram of competition between exactly one traditional and open-access journal. Journals' best-response functions are drawn as dark curves. Both are the standard solution to respective first-order conditions except that, if the traditional journal's price p^a_t is sufficiently high, the open-access operates as a monopolist because its higher quality good no longer faces effective competition from the traditional journal for authors. This accounts for the vertical portion of the open-access journal's best response function at its monopoly price. Equilibrium is given by the intersection of the best-response functions BR^a_t and BR^a_o.

Equilibrium for industry configurations with other combinations of journal types can also be represented in the figure. Consider the configuration with a single traditional and several open-access journals, i.e., $|T| = 1$ 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. The axes in Figure 5 have been scaled so that the origin reflects zero-profit prices. Hence equilibrium in this configuration is given by the intersection of BR_t^a with the vertical axis. The traditional journal is not driven completely out of the market because the profit earned on readers can be used to subsidize lower submission fees, attracting authors with a low marginal rate of substitution between price and readership as indexed by v^a. Still, the stronger competition provided by the second open-access entrant induces the traditional journal to reduce its submission fee and cuts into its profit. Once two open-access journals have entered, further open-access entry has no effect on equilibrium prices or profits.

Analogously, equilibrium with several traditional journals and a single open-access journal—i.e., $|T| \geq 2$ and $|O| = 1$—is given by the intersection of BR_o^a with the horizontal axis. Entry by a second traditional journal induces the open-access journal to reduce its submission fee and cuts into its profit. Further entry by traditional journals beyond the second has no effect on equilibrium prices or profit earned by the set of journals of one type.[11]

In the configuration with more than one of both traditional and open-access journals, the equilibrium submission fee is driven down to the zero-profit level for both types of journal, corresponding to the origin of the graph. Thus entry of a second traditional journal when there is existing competition from two or more open-access journals has no effect on open-access journals' prices but reduces the traditional journal's price. Entry of a second open-access journal when there is existing competition from two or more traditional journals has the inverse effect.

Although we have already solved for equilibrium with a monopoly journal and equilibrium with competition involving just one type of journal, for completeness these configurations, too, can be represented in the figure. Equilibrium with a monopoly traditional journal is indicated by the intersection of BR_t^a with the dotted horizontal line at the "choke price" $\bar{v}^a$. (The price for the

[11] If the zero-price constraint binds, allowing traditional journals to earn positive profit, the total is divided among more participants as more of them enter.

absent journal is somewhat arbitrary, but setting it at or above the "choke price" is a straightforward way to indicate it.) Analogously, equilibrium with a monopoly open-access journal is indicated by the intersection of BR_o^a with the dotted vertical line at $\bar{v}^a$. Equilibrium with competing traditional journals is indicated by the point at the lower right of the figure at which the horizontal axis (the level to which Bertrand competition among traditional journals drives price down) meets the dotted vertical line for the open-access "choke price." Equilibrium with competing open-access journals is given by the analogous point at the upper left of the figure.

6. Non-Profit Journals

So far we have analyzed the case of for-profit journals. In this section we explore how the analysis changes for non-profit journals. This is an important case to study because in practice many journals on various topics and in various subfields are published by societies, universities, and other non-profits. In economics, for example, the top five journals ranked as noted in Table 1 are all non-profits. All of the open-access economics journals in Table 2 are published by non-profits.

The complication in studying non-profits 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 non-profit objectives.

The case of a non-profit open-access journal is straightforward. The subscription fee is given by the nature of the journal. Whatever the non-profits objective, it is unlikely this would lead to a higher-than-monopoly submission fee. Therefore, a non-profit open-access journal would typically charge a lower submission fee than a for-profit. How much lower depends on the specific objectives as well as the availability of external funds from grants or lines of business to subsidize losses if such are experienced. In the example of the journals in Table 2, only one (*Annals of the University of Petrosani: Economics*) charges an author fee. The rest have neither a submission nor a subscription fee, so must have an external source to fund the journal's operation.

The case of a non-profit 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, non-profit 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 non-profit status. It is theoretically possible that a non-profit 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 non-profit journals, allowing a balance of low author and reader fees without constraining the reader fees to be exactly zero, which as shown in Section 3 may not be efficient. This may explain why many non-profits have not gone the open-access route. For example, none of the top non-profit economics journals in Table 1 have. However, open-access may be optimal for the non-profit, consistent with the policies of the journals in Table 2.

7. Hybrid Pricing Strategy

In this section 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 begun experimenting with this pricing strategy. For example, Elsevier, Springer, and Wiley recently instituted a policy of charging authors a $3,000 premium for open access; all of the journals in Table 1 exhibiting a $3,000 author fee for open access (*Economic Journal* and so forth) fall under this policy. Springer calls this hybrid hybrid pricing strategy "Open Choice"; Wiley calls it "OnlineOpen."

We model a hybrid journal as follows. We will 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 $p^a + x^a$. Journal costs and author and reader benefits are the same as above.

7.1. 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 4.1. 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 4.2. 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: do not submit, submit and opt for traditional access, or submit and opt for open access. Author behavior is similar to that described in Section 5.3 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. Appendix B contains a detailed analysis of the author's equilibrium strategy in this continuation game. It is proved that the set of author types is partitioned into three subintervals: 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 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). To streamline the analysis, here 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. The appendix provides sufficient conditions for this case to arise in equilibrium.

Figure 6 provides a schematic diagram of the author's strategy for different possible types. Authors with the lowest value of v^a do not submit articles; authors with intermediate values submit under traditional access; authors with the highest values submit an article, paying the premium for open access. 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 $v^a = p^a/q^a_{mt}$, as shown in the figure. The boundary between the last two subintervalus 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 $v^a = x^a/(1-q^a_{mt})$, as shown in the figure. 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 maximize profit:

$$(p^a - c^a + \pi^r_{mt}) \left[F^a\left(\frac{x^a}{1-q^r_{mt}}\right) - F^a\left(\frac{p^a}{q^r_{mt}}\right)\right] + (p^a + x^a - c^a - c^r)\left[1 - F^a\left(\frac{x^a}{1-q^r_{mt}}\right)\right], \tag{12}$$

or, rearranging,

$$(p^a - c^a + \pi^r_{mt}) Q^a(p^a, q^r_{mt}) + (x^a - c^a - \pi^r_{mt}) Q^a(x^a, 1 - q^r_{mt}). \tag{13}$$

The first term is identical to the profit for a monopoly traditional journal from (6). 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

$$L^a_{mhx} \equiv \frac{x^a_{mh} - (1-q^r_{mt})c^r}{x^a_{mh}} = \frac{1}{|\eta^a_{mhx}|} + \frac{p^r_{mt} q^r_{mt}}{x^a_{mh}}. \tag{14}$$

where η^a_{mhx} is the elasticity of author demand for open access evaluated at the equilibrium premium, i.e.,

$$\eta^a_{mhx} \equiv \frac{Q^a_1(x^a_{mh}, 1-q^r_{mt}) x^a_{mh}}{Q^a(x^a_{mh}, 1-q^r_{mt})}. \tag{15}$$

There are several points to notice about (14). 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

$$[Q^a(p^a_{mt}, q^r_{mt}) - Q^a(x^a_{mh}, 1 - q^r_{mt})]p^r_{mt} \tag{16}$$

and number of readers with access to the article is

$$Q^a(p^a_{mt}, q^r_{mt})q^r_{mt} + Q^a(x^a_{mh}, 1 - q^r_{mt})(1 - q^r_{mt}). \tag{17}$$

Summarizing the preceding analysis, we have the following proposition.

Proposition 10. *Assume that, in equilibrium, the monopoly hybrid journal serves a positive measure of authors choosing traditional access and a positive measure choosing open access (sufficient conditions given in Appendix B). 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* (16) *and expected number of readers who access the article by* (17)*.*

Proposition 10 is consistent with some stylized empirical facts concerning economics journals. So far, the large commercial publishers, who recently moved to hybrid from the traditional pricing model have not made marked changes to their basic submission fees. Subscription fees have risen more slowly than historically, even declining slightly for some journals, perhaps reflecting an average fee for access to articles, a small proportion of which are now freely accessible on the Internet.

7.2. 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 5 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 5. 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 5. 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 $|T| \geq 2, |O| \geq 2$.

Hybrid journals tend to be quite profitable in the monopoly setting (see Proposition 11 for a result on this count) because it provides the journal with another instrument for surplus extraction. Unfortunately for the journal, this extra instrument intensifies competition when other journals are present in the market, reducing profits.

7.3. Predation

The results from the previous section imply that a single traditional journal competing against an open-access journal would find it unprofitable to move to a hybrid model by adding an open-access option. Such a move would shift the competitive outcome in Figure 5 from the point labeled $|T| = 1, |O| = 1$ to the point labeled $|T| = 1, |O| \geq 2$. The open-access price would be driven down to cost, so the hybrid journal would earn no profit on any submissions to its open-access operations, and it would lose some of its previous traditional submissions, cannibalized by the reduced open-access price.

Outside of the model, predation would provide one reason for the traditional journal to move to hybrid access. The journal would sacrifice profits in the short run for the long-term gain of curtailing the operations of an open-access competitor or leading to its exit.[12] The analysis would be identical for the case of a traditional journal creating a spin-off journal offering open access as a sort of fighting brand to reduce the profits of an open-access competitor. One recently publicized case is the launch by *Nature* of *Scientific Reports* as a direct competitor to the open-access journal *PLoS One*. The new journal's mission statement is similar to *PLoS One*'s and it has an identical author fee of $1,350.[13]

We emphasize that our results on predation are speculative because they are outside the model. We have no evidence that any particular journal initiative is predatory. A reasonable alternative in each instance is that the changes in the journal market made the initiative profitable.

[12] See Milgrom and Roberts (1982) for a model of rational limit pricing to signal product-market information and Bolton and Scharfstein (1990) for a model of rational predation to exhaust limited financial capital.

[13] Commentators such as Davis (2011) have warned of possible predatory effects of the launch *Scientific Reports*: "...Nature has entered the ring fighting with both fists. And if Nature fails to deliver a knockout, *BMJ Open* is standing right behind them with gloves ready."

8. Endogenous Reader Cost

Thus far, we have assumed that the marginal cost of serving a reader, c^r, can take on any non-negative value and is the same across traditional and open-access journals. This allows for a general analysis of the journals market applicable to the earlier print era, when the cost of delivering a hard copy to each reader certainly entailed $c^r > 0$ as well as the Internet era, in which delivery costs are effectively reduced to near zero.

In this section, we analyze an alternative assumption about costs that is increasingly relevant as the journal market moves further away from print toward digital access. Assume that articles are delivered to readers over the Internet at no cost. The only remaining cost of serving a reader is the cost of processing the reader's account. This may differ across kinds of journals. Hence we introduce new notation to distinguish between the reader cost for traditional journals (c_t^r) and open-access journals (c_o^r). An open-access journal does not need to keep track of reader accounts because articles are freely posted. Hence we assume $c_o^r = 0$. Traditional journals may face a cost of processing reader accounts, so $c_t^r \geq 0$.

The possibility that $c_o^r < c_t^r$ provides an additional advantage to open over traditional access. The analysis behind Proposition 4 could be used to prove that the submission fee for a monopoly open-access is lower after imposing the new cost assumption, but it would still charge a weakly higher submission fee than a monopoly traditional journal. Of course, the reduction in an open-access journal's costs would mean that it is more profitable than a traditional journal under a broader range of parameters (see Proposition 5 for a comparison of profits). Regarding competition, a reduction in the reader cost only for an open-access journal would show up as a (weak) leftward shift in the best-response function BR_o^a of an open-access journal. Effectively, this increase in the competitiveness of open-access journals would lead to weakly lower author fees in any configuration involving some of this kind of journal.

Traditional journals would have a natural response to the existence of high costs of processing reader accounts. By bundling journals together, a publisher can spread the fixed cost of negotiating with a reader and servicing the reader's account over the number of journals in the bundle. For the largest publishers, this can result in substantial savings on reader costs per journal. Elsevier, which publishes over 2,000 journals, this reader cost is spread over enough journals that it is effectively zero for any single journal.

One implication of the model of this section is that bundling reduces reader costs more for traditional than for open-access journals, because bundling would have no effect on the (zero) reader cost for the latter kind of journal. A possible empirical implication is that a higher proportion of traditional than open-access journals would be offered as a bundle.[14]

9. Conclusion

In this conclusion, we will summarize the theoretical results, focusing on the most empirically or policy relevant findings. With virtually free electronic distribution and no need to administer reader accounts, it is approximately true that reader costs are zero (i.e., $c^r = 0$) under open access. When $c^r = 0$, our results showed that open access is first-best efficient.

This result should not be taken to say that open access is universally better than traditional access. Take the case of a for-profit monopoly journal, which may serve as a simple metaphor for a market in which journals have a source of market power from outside the model even if incomplete. Equilibrium with a traditional journal may be more efficient than with an open-access journal. The traditional journal earns some profit from the reader side. To boost these profits, the journal seeks to obtain more submissions by shading its author fees below what a for-profit open-access journal would charge. Offsetting the lower author prices are excessively high reader prices. By excessively high, we mean that the subscription fees are higher than the journal itself would like to charge if it could commit to the fees ex ante. This inability to commit leads to a hold-up problem between the journal and authors, which is addressed by the crude commitment on the part of open-access journals to zero submission fees.

[14] A possible complication is that bundling may produce efficiencies on the author side. There may be fixed costs of setting up an Internet portal to post the articles that can be spread across a number of journals published by the same enterprise. Because there is less need to restrict access for individual journals, there may be bigger scope economies associated with publishing open-access journals through a common portal than with traditional journals.

Whether traditional or open-access journals are more efficient depends on whether low author or reader fees contribute more to social surplus. If the distribution of author benefits from readership are sufficiently high, then ensuring wide readership with low subscription fees is more important, and open-access is socially more efficient. If the distribution of author benefits is scaled up enough, equilibrium ends up selecting open access. Conversely, if the distribution of author benefits shrinks, then under an additional condition that reader benefits are at least moderate, ensuring enough submissions from which readers benefit becomes important. This is accomplished with traditional access.

Notice that the conditions under which alternative forms of access are efficient are the converse of conventional wisdom. Commentators have argued in favor of open access mainly from the perspective of the reader benefits it provides. The relative efficiency of open access in fact is from the indirect benefits derived by authors. This result is paradoxical at first glance, but follows from further consideration from the logic of two-sided markets. An examination of Figure 4 does provide some basis for the scholarly community's concern about traditional access. While there is a region in which open-access is inefficiently selected in equilibrium just as there is a region in which traditional access is inefficiently selected, the former region involves low values of author and reader benefits, bounding how much surplus can be lost. Traditional access is inefficiently selected for higher benefit levels, leading so the losses from inefficiencies are magnified.

We also analyzed the case of competing journals. Perhaps the most striking finding here is that traditional journals, though offering perfect substitutes in the model, can still earn positive profits. They do not dissipate all profit in the competition for authors because they cannot charge negative submission fees and cannot commit to low subscription fees, which would be attractive to authors. The subscription fee is the same with competing traditional journals as a monopoly journal would charge. Somewhat paradoxically, a necessary condition for traditional journals to earn positive profits is a zero submission fee. This indicates that journals hit a zero-price constraint before they hit a zero-profit constraint, and thus can retain some profits. Competition is in a sense more severe among open-access journals. While competing traditional journals can earn positive profit, competing open-access journals always earn zero profit in the model. This sort of asymmetry in competitive effects follows because open-access journals earn no profit from readers. As Bertrand competition for authors drives submission fees down, open-access journals hit the zero-profit bound before they hit the zero-price bound.

Competition between a traditional and an open-access journal delivers a similar outcome as competition in vertical-quality models. An open-access journal is a commitment to high quality valued by an author in the sense of wide access. Thus the open-access journal serves author types who value wide access, charging them a high submission fee; the traditional journal serves author types who do not value access as much, at a lower submission fee. Our results imply that entry of an open-access journal in a market with an existing monopoly traditional journal would have no effect on subscription fee the traditional journal charges conditional on receiving a submission. However, in a model with multiple authors rather than a representative one, the total subscription fee would fall for the traditional journal because it would publish fewer articles, losing some to the open-access journal. This result would explain a a striking finding from our empirical analysis in the introduction. While past empirical studies consistently documented price increases even beyond 2000, our results suggest a large recent drop. While Bergstrom (2001) found that the ratio between the average submission fee for the top-ten for-profit economics journals was 7.1 times higher than that for the top-ten non-profit journals at the end of the 1990s, and our own analysis showed this ratio rose to 8.5 by the middle of the 2000s, using the data in Table 1 one can show that this ratio has recently fallen in half to 3.9 (taking the ratio of means). To our knowledge, we are the first to document this recent price fall. While there may be a number of explanations for this price fall—reduction in journal demand due to falling library budgets in the economic downturn, coordinated pressure by scholarly societies to keep prices down with the threat of boycotts at the author and editorial levels—our model offers another explanation in the form of actual and potential competition for traditional journals from open-access journals.

We analyzed a number of extensions to the model that have empirical and policy relevance. Our extension to non-profit journals provided mixed messages for whether open access is more or less likely to be observed for such journals. On the one hand, because they do not claim residual profits, non-profit journals do not necessarily suffer as much from the hold-up problem of excessively high subscription fees. Thus the main benefit of open access in our model—commitment to low reader prices—may not be as valuable to a non-profit journal. A non-profit journal with the mission of maximizing social welfare may through its very mission statement be able to achieve a more nuanced commitment to efficient prices, which might be positive on the reader side in a second-best world, not zero. That said, if the non-profit journal adopts wide access as its core mission rather than social-welfare maximization, it can use whatever rents are generated to subsidize open access.

The analysis of hybrid pricing, whereby a traditional journal adds an option for authors to pay an extra fee to have their articles available to readers for free, is relevant to the market because the major publishers have all added such options. In a monopoly market, having a richer menu of prices increases profits. In an competitive environment, we found that the hybrid strategy makes the journal a fiercer competitor, as if two separate journals, one traditional, one open-access, were added to the market.

Appendix A: Proofs of Propositions

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

Proof of Proposition 1: Differentiating (2) with respect to p^r gives

$$\left[\int_{p^r}^{\bar{v}^r}\left(c^r-\frac{p^a}{Q^r(p^r)}-v^r\right)dF^r(v^r)+c^a\right]\frac{p^a f^r(p^r)}{Q^r(p^r)^2} \tag{A1}$$

$$+\int_{p^a/Q^r(p^r)}^{\bar{v}^a}(c^r-v^a-p^r)f^r(p^r)dF^a(p^a). \tag{A2}$$

Differentiating (2) with respect to p^a gives

$$\int_{p^r}^{\bar{v}^r}\left(c^r-\frac{p^a}{Q^r(p^r)}-v^r\right)dF^r(v^r)+c^a. \tag{A3}$$

If p_s^a is an interior solution, then (A3) equals 0 by the first-order condition, implying that the first factor in (A1) equals 0. If $p_s^a=0$, then the second factor in (A2) equals 0. In either case, only the term (A2) remains. Setting (A2) equal to 0 and solving the resulting first-order condition for p^r gives

$$c^r-\frac{\int_{p^a/Q^r(p^r)}^{\bar{v}^a}v^a dF^a(v^a)}{1-F^a(p^a/Q^r(p^r)}=c^r-E(v^a|v^a>p^a/Q^r(p^r)).$$

The first-best subscription fee p_{fb}^r equals (A4) or 0, whichever is greater. Setting (A3) equal to 0 and solving the resulting first-order condition for p^a gives

$$c^a-\int_{p^r}^{\bar{v}^r}(v^r-c^r)dF^r(v^r)=c^r-E(v^r-c^r|v^r>p^r)\Pr(v^r>p^r). \tag{A4}$$

The first-best submission fee p_{fb}^a equals (A4) or 0, whichever is greater.□

Proof of Proposition 4: We prove the result by nesting the objective functions of the two types of journal together using the parameter θ and then applying Edlin and Shannon's (1998) Strict Monotonicity Theorem 1 to provide the necessary comparative statics result with respect to θ.

Nesting the ex-ante expected profit function for a traditional journal, (6), with that for an open-access journal, (9), yields

$$\pi_m=[p^a-c^a+(1-\theta)\pi_{mt}^r-\theta c^r]\left[1-F^a\left(\frac{p^a}{(1-\theta)q_{mt}^r+\theta}\right)\right], \tag{A5}$$

where $\theta=0$ for a traditional journal and $\theta=1$ for an open-access journal. A few remarks about this objective function are in order. First, the reader can verify that (A5) is a total (ex-ante) profit function because it includes the continuation profits from ex post stages. Note second that this is a single-dimensional choice problem. Only p^a is an endogenous variable; the rest including π_{mt}^r and q_{mt}^r are independent of p^a.

The first-order condition associated with (A5) is

$$\frac{\partial \pi_m}{\partial p^a} = 1 - F^a - \frac{[p^a - c^a + (1-\theta)\pi^r_{mt} - \theta c^r] f^a}{(1-\theta) q^r_{mt} + \theta}, \tag{A6}$$

where the argument of F^a, shown in (A5), has been supressed for brevity, as has the argument of f^a. Differentiating this condition again,

$$\frac{\partial^2 \pi_m}{\partial p^a \partial \theta} = \frac{(1-q^r_{mt}) f^a}{(1-\theta) q^r_{mt} + \theta} \left\{ \frac{\pi^r_{mt} + c^r}{1 - q^r_{mt}} + \frac{2p^a - c^a + (1-\theta)\pi^r_{mt} - \theta c^r}{(1-\theta) q^r_{mt} + \theta} + \frac{[p^a - c^a + (1-\theta)\pi^r_{mt} - \theta c^r] p^a}{[(1-\theta) q^r_{mt} + \theta]^2} \left(\frac{f^{a\prime}}{f^a} \right) \right\}. \tag{A7}$$

To determine the sign of (A6), we now impose the condition that the distribution of author benefits has a nondecreasing hazard rate. Then

$$\frac{f^{a\prime}}{f^a} \geq -\frac{f^a}{1-F^a} \tag{A8}$$

$$= -\frac{(1-\theta) q^r_{mt} + \theta}{p^a - c^a + (1-\theta)\pi^r_{mt} - \theta c^r}. \tag{A9}$$

To see (A8), define the hazard rate $h^a \equiv f^a/(1-F^a)$. The monotone hazard rate condition $h^{a\prime} \geq 0$ implies (A8). Equation (A9) follows from setting (A6) equal to zero and rearranging.

Substituting (A9) into (A7) and collecting terms yields

$$\frac{\partial^2 \pi_m}{\partial p^a \partial \theta} \geq \frac{(1-q^r_{mt}) f^a}{(1-\theta) q^r_{mt} + \theta} \left[\frac{\pi^r_{mt} + c^r}{1 - q^r_{mt}} + \frac{p^a - c^a + (1-\theta)\pi^r_{mt} - \theta c^r}{(1-\theta) q^r_{mt} + \theta} \right] \tag{A10}$$

$$> 0. \tag{A11}$$

Condition (A11) holds because the monopoly journal makes strictly positive profit, so the unit margin $p^a - c^a + (1-\theta)\pi^r_{mt} - \theta c^r$ must be strictly positive.

We have thus shown that (A5) has strictly increasing marginal returns. Proposition 3 states that p^a_{mo} is an interior solution. Strict Monotonicity Theorem 1 then implies $p^a_{mo} > p^a_{mt}$. □

Proof of Proposition 5: To prove the first statement of the proposition, let random variable $\omega^a = \theta^a v^a$ denote the scaled author value, with distribution function Φ^a, density ϕ^a, and support

$[0, \bar{\omega}^a]$. Total profit for a monopoly traditional journal is

$$\begin{aligned}
\pi_{mt} &= \max_{p^a \geq 0} \left\{ (p^a - c^a + \pi^r_{mt}) \left[1 - \Phi^a \left(\frac{p^a}{q^r_{mt}} \right) \right] \right\} && \text{(A12)} \\
&= \max_{p^a \geq 0} \left\{ (p^a - c^a + \pi^r_{mt}) \left[1 - F^a \left(\frac{p^a}{\theta^a q^r_{mt}} \right) \right] \right\} && \text{(A13)} \\
&= \theta^a \max_{z^a \geq 0} \left\{ \left(q^r_{mt} z^a + \frac{\pi^r_{mt} - c^a}{\theta^a} \right) [1 - F^a(z^a)] \right\} && \text{(A14)} \\
&= \theta^a \left(q^r_{mt} z^a_{mt} + \frac{\pi^r_{mt} - c^a}{\theta^a} \right) [1 - F^a(z^a_{mt})], && \text{(A15)}
\end{aligned}$$

where z^a_{mt} is the maximizer of (A14). Equation (A13) follows from the formula for the distribution function of a transformed random variable, (A14) from the change of variables $z^a = p^a/\theta^a q^r_{tm}$, and (A15) from the definition of z^a_{mt} as a maximizer. Applying similar steps to the total profit for a monopoly open-access journal,

$$\begin{aligned}
\pi_{mo} &= \max_{p^a \geq 0} \{ (p^a - c^a - c^r)[1 - \Phi^a(p^a)] \} && \text{(A16)} \\
&= \max_{p^a \geq 0} \left\{ (p^a - c^a - c^r) \left[1 - F^a \left(\frac{p^a}{\theta^a} \right) \right] \right\} && \text{(A17)} \\
&= \theta^a \max_{z^a \geq 0} \left\{ \left(z^a - \frac{c^a + c^r}{\theta^a} \right) [1 - F^a(z^a)] \right\} && \text{(A18)} \\
&= \theta^a \left(z^a_{mo} - \frac{c^a + c^r}{\theta^a} \right) [1 - F^a(z^a_{mo})], && \text{(A19)}
\end{aligned}$$

where z^a_{mo} is the maximizer of (A18).

Before proceeding, we prove two useful equalities. First,

$$\lim_{\theta^a \to \infty} z^a_{mt} = \operatorname*{argmax}_{z^a \geq 0} \{ z^a [1 - F^a(z^a)] \} = \lim_{\theta^a \to \infty} z^a_{m0}, \tag{A20}$$

where the first equality holds because z^a_{mt} maximizes (A14) and the second because z^a_{mo} maximizes (A18). But (A20) implies

$$\lim_{\theta^a \to \infty} \{ z^a_{mt} [1 - F^a(z^a_{mt})] \} = \lim_{\theta^a \to \infty} \{ z^a_{m0} [1 - F^a(z^a_{m0})] \}. \tag{A21}$$

Returning to the proof, substituting from (A15) and (A19) and simplifying yields

$$\frac{\pi_{mt}}{\pi_{mo}} = \frac{[q^r_{mt} z^a_{mt} + (\pi^r_{mt} - c^a)/\theta^a][1 - F^a(z^a_{mt})]}{z^a_{mo} - (c^a + c^r)/\theta^a][1 - F^a(z^a_{mo})]}. \tag{A22}$$

Thus

$$\lim_{\theta^a \to \infty} \frac{\pi_{mt}}{\pi_{mo}} = \frac{q^r_{mt} \lim_{\theta^a \to \infty} \{z^a_{mt}[1 - F^a(z^a_{mt})]\}}{\lim_{\theta^a \to \infty} \{z^a_{mo}[1 - F^a(z^a_{mo})]\}} \tag{A23}$$

$$= q^r_{mt} \tag{A24}$$

$$< 1, \tag{A25}$$

where (A23) follows from taking limits in (A22) and (A24) follows from (A21). To see (A25), note Proposition 3 states that $p^r_{mt} > 0$. Thus $q^r_{mt} < 1$ because the support of v^a begins at 0, so the interval $[0, p^a_{mt}]$ has positive measure. Thus $\pi_{mt} < \pi_{mo}$ for sufficiently high θ^a.

To prove the second statement of the proposition, 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

$$\pi_{mt} = \max_{p^a \geq 0} \left\{ (p^a - c^a + \pi^r_{mt}) \left[1 - F^a \left(\frac{p^a}{q^r_{mt}} \right) \right] \right\} \tag{A26}$$

$$\geq \pi^r_{mt} - c^a \tag{A27}$$

$$= \max_{p^r \geq 0} \{ (p^r - c^r)[1 - \Phi^r(p^r)] \} - c^a \tag{A28}$$

$$= \max_{p^r \geq 0} \left\{ (p^r - c^r) \left[1 - F^r \left(\frac{p^r}{\theta^r} \right) \right] \right\} - c^a \tag{A29}$$

$$\geq \theta^r \max_{z^r \geq 0} \{ z^r [1 - F^r(z^r)] \} - c^a - c^r. \tag{A30}$$

Step (A27) holds because $p^a = 0$ is not necessarily a maximizer of (A26), (A28) holds by definition, (A29) holds by the formula for the distribution of a transformed random variable, and (A30) holds by change of variable $z^r = p^r/\theta^r$ and by subtracting off a full c^r. Now

$$\max_{z^r \geq 0} \{ z^r [1 - F^r(z^r)] \} > 0. \tag{A31}$$

Hence (A30) 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

$$\pi_{mo} = \max_{p^a \geq 0} \{ (p^a - c^a - c^r)[1 - F^a(p^a)] \}. \tag{A32}$$

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:

$$\begin{aligned}
\pi_{mt}^r &= \max_{p^r \geq 0} \{(p^r - c^r)[1 - \Phi^r(p^r)]\} && \text{(A33)}\\
&\leq \max_{p^r \geq 0} \{p^r[1 - \Phi^r(p^r)]\} && \text{(A34)}\\
&= \max_{p^r \geq 0} \left\{ p^r \left[1 - F^r \left(\frac{p^r}{\theta^r} \right) \right] \right\} && \text{(A35)}\\
&= \theta^r \max_{z^r \geq 0} \{z^r[1 - F^r(z^r)]\}, && \text{(A36)}
\end{aligned}$$

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 (A36) then implies $\lim_{\theta^r \to 0} \pi_{mt}^r = 0$. Reader quantity can also be bounded. We have $q_{mt}^r \leq 1 - \Phi^r c^r = 1 - F^r(c^r/\theta^r)$. Hence $0 \leq \lim_{\theta^r \to 0} q_{mt}^r \leq \lim_{\theta^r \to 0}[1 - F^r(c^r/\theta^r)] = 0$, implying $\lim_{\theta^r \to 0} q_{mt}^r = 0$.

Applying these insights to total profit for a monopoly traditional journal, for any given author price p^a, the limit of author quantity is $\lim_{\theta^r \to 0}[1 - F^a(p^a/q_{mt}^r)] = 0$. 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 $0 \leq q_{mo}^a \leq 1 - \Phi^a c^a = 1 - F^a(c^a/\theta^a)$. But $c^a > 0$ implies $\lim_{\theta^a \to 0}[1 - F^a(c^a/\theta^a)] = 0$, in turn implying $\lim_{\theta^a \to 0} q_{mo}^a = 0$. 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

$$\begin{aligned}
\pi_{mt} &= \max_{p^a \geq 0} \{(p^a - c^a + \pi_{mt}^r)[1 - \Phi^a(p^a)]\} && \text{(A37)}\\
&\geq \pi_{mt}^r - c^a && \text{(A38)}\\
&> 0, && \text{(A39)}
\end{aligned}$$

where (A38) holds upon substituting $p^a = 0$, which is not necessarily a maximizer of (A37), and (A39) holds under the maintained condition $\pi_{mt}^r > c^a$. Under that condition, $\pi_{mt} > 0 = \pi_{mo}$. □

Proof of Proposition 7: To prove the first statement of the proposition, let random variable $\omega^a = \theta^a v^a$ denote the scaled reader value, with distribution function, density, and support as given in the proof of Proposition 5. Equilibrium social welfare with a monopoly traditional journal is

$$
\begin{aligned}
SW_{mt} &= \int_{p^a_{mt}/q^r_{mt}}^{\bar{\omega}^a} \left[\int_{p^r_{mt}}^{\bar{v}^r} (\omega^a + v^r - c^r) dF^r(v^r) - c^a \right] \phi^a(\omega^a) d\omega^a & \text{(A40)} \\
&= \int_{p^a_{mt}/q^r_{mt}}^{\bar{\omega}^a} \left[\int_{p^r_{mt}}^{\bar{v}^r} (\omega^a + v^r - c^r) dF^r(v^r) - c^a \right] f^a\left(\frac{\omega^a}{\theta^a}\right) d\omega^a & \text{(A41)} \\
&= \int_{p^a_{mt}/\theta^a q^r_{mt}}^{\bar{v}^a} \left[\int_{p^r_{mt}}^{\bar{v}^r} (\theta^a v^a + v^r - c^r) dF^r(v^r) - c^a \right] dF^a(v^a) & \text{(A42)} \\
&= \theta^a \int_{z^a_{mt}}^{\bar{v}^a} \left\{ q^r_{mt} v^a + \frac{1}{\theta^a} \left[\int_{p^r_{mt}}^{\bar{v}^r} (v^a - c^r) dF^r(v^r) - c^a \right] \right\} dF^a(v^a), & \text{(A43)} \\
& & \text{(A44)}
\end{aligned}
$$

where (A40) follows from (2), (A41) from the formula for the density of a transformed random variable, (A42) by the change of variables $\omega^a = \theta^a v^a$ in the integral, and (A43) by substituting the maximizer z^a_{mt} of (A14) and rearranging. Similar steps show that equilibrium social welfare with a monopoly open-access journal is

$$
\begin{aligned}
SW_{mo} &= \int_{p^a_{mo}}^{\bar{\omega}^a} \left[\int_{0}^{\bar{v}^r} (\omega^a + v^r - c^r) dF^r(v^r) - c^a \right] \phi^a(\omega^a) d\omega^a & \text{(A45)} \\
&= \theta^a \int_{z^a_{mo}}^{\bar{v}^a} \left\{ v^a + \frac{1}{\theta^a} [E(v^r) - c^a - c^r] \right\} dF^a(v^a), & \text{(A46)} \\
& & \text{(A47)}
\end{aligned}
$$

where z^a_{mo} is the maximizer of (A18). Dividing,

$$
\frac{SW_{mt}}{SW_{mo}} = \frac{\int_{z^a_{mt}}^{\bar{v}^a} \left\{ q^r_{mt} v^a + \frac{1}{\theta^a} \left[\int_{p^r_{mt}}^{\bar{v}^r} (v^a - c^r) dF^r(v^r) - c^a \right] \right\} dF^a(v^a)}{\int_{z^a_{mo}}^{\bar{v}^a} \left\{ v^a + \frac{1}{\theta^a} [E(v^r) - c^a - c^r] \right\} dF^a(v^a)}. \tag{A48}
$$

Taking limits,

$$
\begin{aligned}
\lim_{\theta^a \to \infty} \frac{SW_{mt}}{SW_{mo}} &= \frac{q^r_{mt} \int_{\lim_{\theta^a \to \infty} z^a_{mt}}^{\bar{v}^a} v^a dF^a(v^a)}{\int_{\lim_{\theta^a \to \infty} z^a_{mo}}^{\bar{v}^a} v^a dF^a(v^a)} & \text{(A49)} \\
&= q^r_{mt} & \text{(A50)} \\
&< 1. & \text{(A51)} \\
& & \text{(A52)}
\end{aligned}
$$

Equation (A49) follows from substituting limits, (A50) from $\lim_{\theta^a \to \infty} z^a_{mt} = \lim_{\theta^a \to \infty} z^a_{m0}$ by (A20), and (A51) from (A25). □

Proof of Proposition 8: Suppose a traditional journal charging p^a receives a submission. Its continuation profit is

$$p^a - c^a + \pi^r_{mt}, \tag{A53}$$

the margin earned on the author plus the expected continuation profit earned from the reader. Setting (A53) equal to zero, the zero-profit submission fee is $c^a - \pi^r_{mt}$. Standard arguments used in the Bertrand game apply here to show that $p^a_{ct} = c^a - \pi^r_{mt}$ if $c^a - \pi^r_{mt} \geq 0$. If $c^a - \pi^r_{mt} < 0$, the zero-profit submission fee violates the non-negativity constraint on prices. The equilibrium submission fee is then determined by the binding constraint: $p^a_{ct} = 0$. □

Appendix B: Detailed Analysis of Hybrid Journal

This appendix provides a full analysis of a monopoly hybrid journal. The text focuses on the non-trivial case in which a hybrid journal provides traditional access to a positive measure of author types and open access to another positive measure of author types. This appendix provides sufficient conditions under which the case analyzed in the text arises.

As discussed in the text, 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

$$v^a < \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right). \tag{B1}$$

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

$$v^a > \max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right). \tag{B2}$$

Because

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

it is immediate that the interval of author values is partitioned into three subintervals as shown in Figure B1, 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 B1 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 B2. 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 B2 in turn, starting with case (i). For there to be a positive measure of non-submitting authors,

$$0 < \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right). \tag{B3}$$

But (B3) requires $p^a > 0$, implying

$$\frac{p^a}{q^r_{mt}} > 0. \tag{B4}$$

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

$$\min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right) < \max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right). \tag{B5}$$

For (B5) to hold, $x^a > 0$. Furthermore, one of the following two conditions must hold:

$$p^a + x^a > \frac{p^a}{q^r_{mt}} \tag{B6}$$

$$p^a + x^a < \frac{x^a}{1 - q^r_{mt}}. \tag{B7}$$

Some algebra shows (B6) and (B7) are equivalent to each other and furthermore are both equivalent to

$$\frac{p^a}{q^r_{mt}} < \frac{x^a}{1 - q^r_{mt}}. \tag{B8}$$

Condition (B6) 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 (B7) 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 B2. 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 $\bar{v}^a$:

$$\frac{p^a}{q^r_{mt}} < \bar{v}^a. \tag{B9}$$

Collecting conditions (B3), (B8), and (B9) yields the necessary and sufficient condition shown in case (i) of Figure B2.

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,

$$\max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right) \le \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right). \tag{B10}$$

Condition (B10) implies

$$\max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right) = \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right) = p^a + x^a. \tag{B11}$$

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 below $\bar{v}^a$:

$$p^a + x^a < \bar{v}^a. \tag{B12}$$

The final step in deriving the necessary and sufficient condition for case (iii) in Figure B2 is to note that (B11) is equivalent to

$$\frac{x^a}{1 - q^r_{mt}} \leq p^a + x^a \leq \frac{p^a}{q^r_{mt}}. \tag{B13}$$

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),

$$\bar{v}^a \leq \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right), \tag{B14}$$

the necessary and sufficient condition shown in case (iv) of Figure B2. For there to be a zero measure of both types who either do not submit or submit under traditional access,

$$\max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right) \leq 0, \tag{B15}$$

which is equivalent to $p^a = x^a = 0$, the indicated condition in case (vii) of Figure B2.

The algebraic conditions for the seven cases in Figure B2 are difficult to envision. Figure B3 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 B2 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 B2 as possible equilibria, leaving cases (i) and (ii) as the only possibilities, as desired. We have the following proposition.

Proposition 11. *A profitable monopoly traditional journal would strictly profit from moving to hybrid pricing if $\bar{v}^a$ is high enough, a sufficient condition being*

$$\bar{v}^a > \frac{c^r + \pi^r_{mt}}{1 - q^r_{mt}}. \tag{B16}$$

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,

$$v^a > \frac{c^r + \pi^r_{mt} + \epsilon}{1 - q^r_{mt}}. \tag{B17}$$

But (B16) ensures that (B17) 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:

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

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.

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Table 1: Fees for Top Economics Journals by Profit Status

Journal	Subscription fee	Submission fee	Author fee for open access
Top ten non-profit journals			
Quarterly Journal of Economics	523	0	—
Econometrica	550	55	—
Journal of Political Economy	777	125	—
American Economic Review	420	200	—
Review of Economic Studies	488	0	—
Journal of Finance	670	140	—
Journal of Labor Economics	633	0	—
Economic Journal	721	79	3,000
Review of Economics & Statistics	500	64	—
RAND Journal of Economics	381	100	—
Median	537	72	3,000
Top ten for-profit journals			
Journal of Economic Growth	803	0	3,000
Journal of Monetary Economics	2,364	250	3,000
Journal of Financial Economics	2,826	550	3,000
Journal of Econometrics	3,378	50	—
Journal of International Economics	1,697	85	3,000
Journal of Economic Theory	3,232	0	—
Journal of Public Economics	2,814	0	3,000
Journal of Development Economics	2,314	0	3,000
European Economic Review	1,835	195	3,000
Review of Economic Dynamics	641	0	3,000
Median	2,339	25	3,000

Sources: Journal ranking from IDEAS/RePEc "Aggregate Ranking for Journals" (website ideas.repec.org/top/-top.journals.all.html), which ranks journals by taking the harmonic mean of seven different individual ranking methods, after dropping the best and worst ranking. Journals that mainly publish solicited articles have been omitted (*Journal of Economic Literature*, *Brookings Papers on Economic Activity*, *Journal of Economic Perspectives* omitted non-profit journals and *Economic Policy* omitted for-profit journal). Profit status from Ted Bergstrom and R. Preston McAfee's website journalprices.com. Subscription fees from Ulrich's Periodicals Directory (website www.ulrichsweb.com/ulrichsweb). Submission and author fees for open-access from individual journal websites. All downloads made on July 7, 2011.

Notes: Dash indicates option for author to pay for open access not available. All fees converted into US$. Subscription fees generally for a single print copy of a volume for an institutional subscriber.

Table 2: Ranked Open-Access Journals in Economics

Journal	IDEAS/RePEc ranking	Year listed on DOAJ	Country
Theoretical Economics	126	2006	USA
Economics Bulletin	144	2003	USA
Economics: The Open-Access, Open-Assessment e-Journal	261	2007	Germany
European Journal of Comparative Economics	337	2004	Italy
Demographic Research	351	2003	Germany
Int'l Journal of Applied Econometrics and Quantitative Studies	369	2007	Spain
CESifo Forum	431	2004	Germany
AUCO Czech Economic Review	460	2009	Czech Republic
Weekly Report	482	2008	Germany
Annals of the University of Petrosani: Economics	490	2009	Romania
Information Technologies and Int'l Development	673	2007	USA

Sources: Journals from Directory of Open Access Journals (DOAJ) dataset (downloaded June 22, 2010 from www.doaj.org) with economics as primary subject area, English as sole language, and appearing on IDEAS/RePEc ranking. The remaining 19 of 31 journals enumerated in Panel B of Figure 1 but not appearing in this table did not obtain a ranking. IDEAS/RePEc ranking taken from "Aggregate Ranking for Journals" (downloaded July 5, 2010 from ideas.repec.org/top/top.journals.all.html).

Notes: See the notes to Table 1 for the IDEAS/RePEc ranking method. Not listed is the *Review of Network Economics*, which offers quasi-open-access, charging a US$300 library subscription fee but allowing free access if a guest-access form is filled out. The *Review of Network Economics* ranked 186. The *Int'l Journal of Applied Econometrics and Quantitative Studies* ceased publishing new articles after 2009.

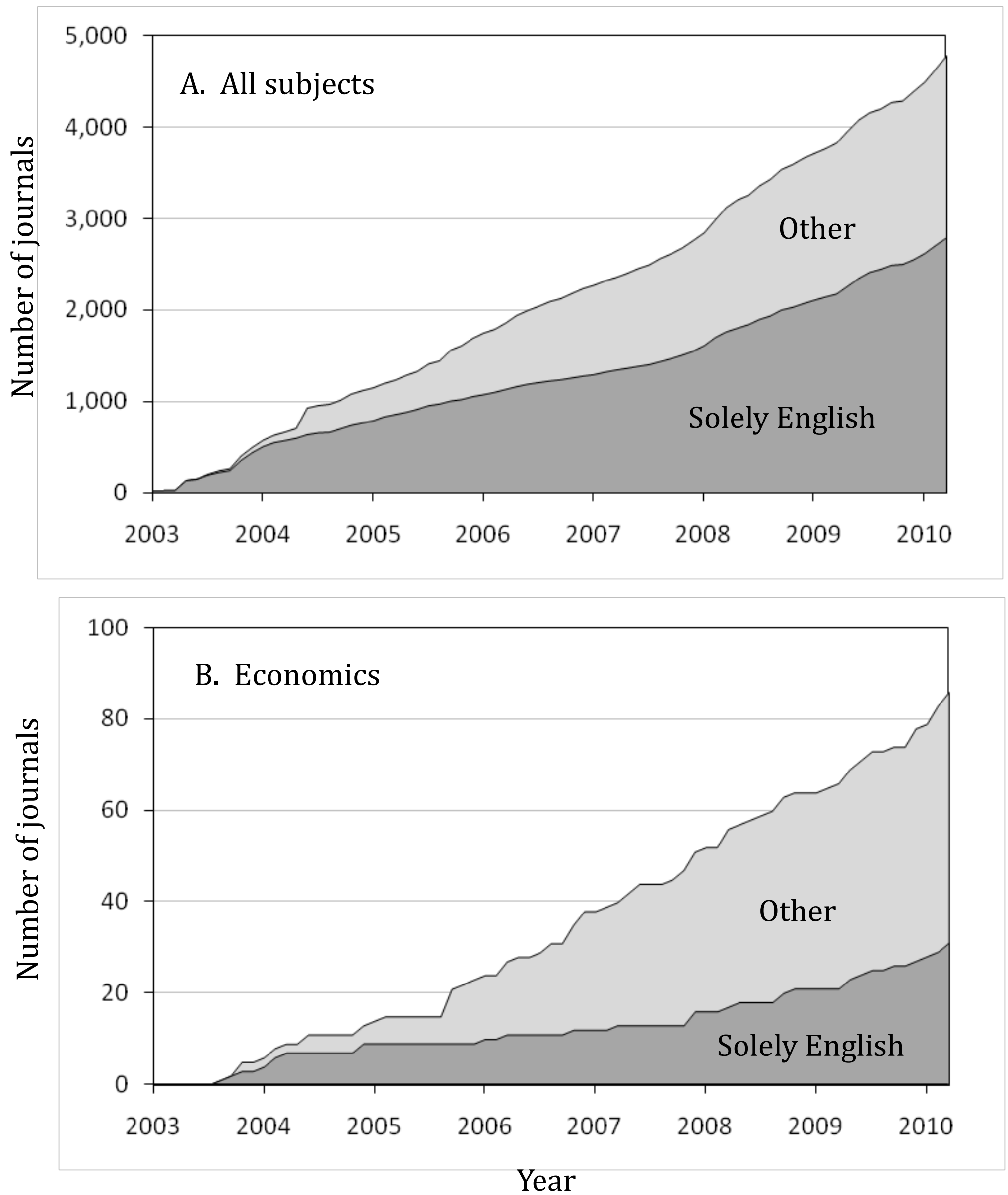

Figure 1: Entry of open-access journals. Shows all disciplines in Panel A and economics in Panel B.

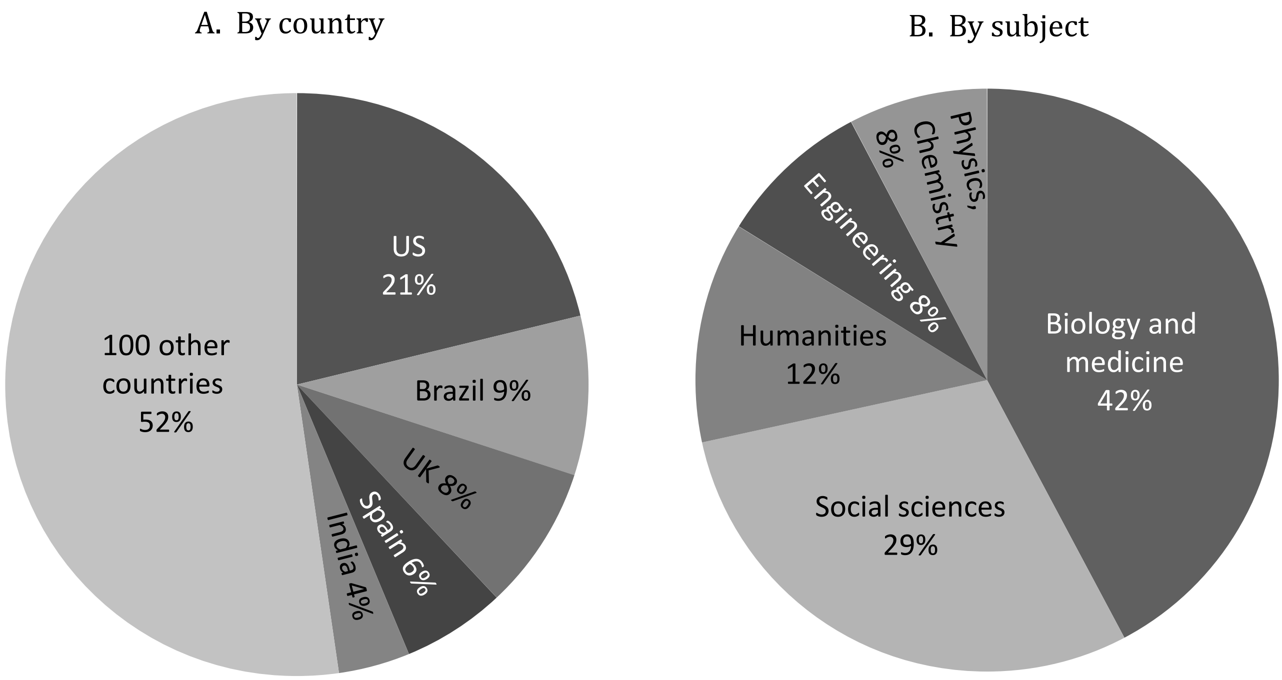

Figure 2: Number of open-access journals. Broken down by country in Panel A and subject in Panel B.

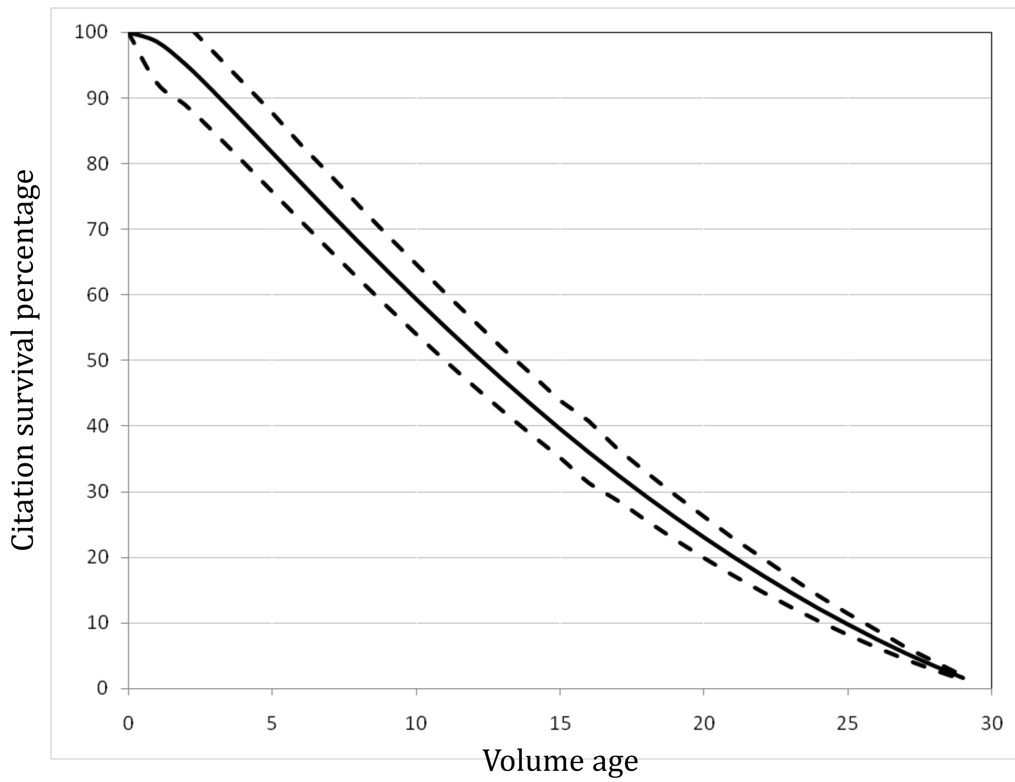

Figure 3: Estimated survival function for economics citations. Measures the citations a volume receives after a given age as a percentage of total citations in the 30 years after publication. Computed from coefficients on fixed age effects from a regression of 1980-2005 cites to all volumes published by 100 of the top economics journals during 1956-2005. Uses Poisson quasi-maximum likelihood procedure (Wooldridge 1999) and includes citation-year and journal fixed effects and digitization indicators. Outside lines bound 95% confidence interval based on robust standard errors clustered by journal.

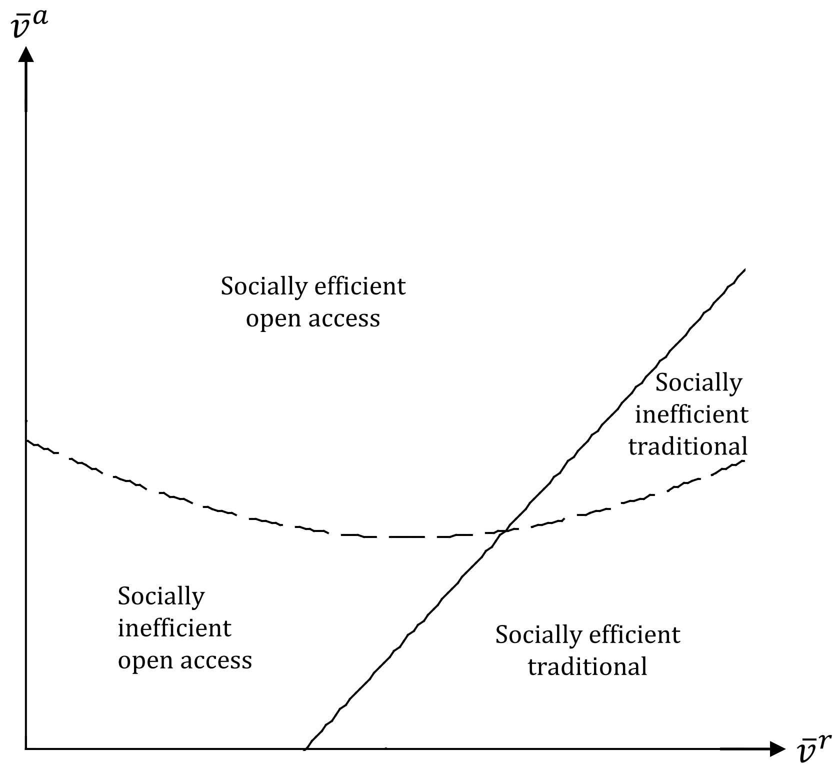

Figure 4: Numerical example illustrating social welfare possibilities. Example involves $c^a = 1/2$, $c^r = 0$, v^a uniformly distributed on $[0, \bar{v}^a]$, and v^r uniformly distributed on $[0, \bar{v}^r]$. Above solid line, open access is more profitable than traditional pricing. Above dotted curve, open access is socially more efficient than traditional pricing.

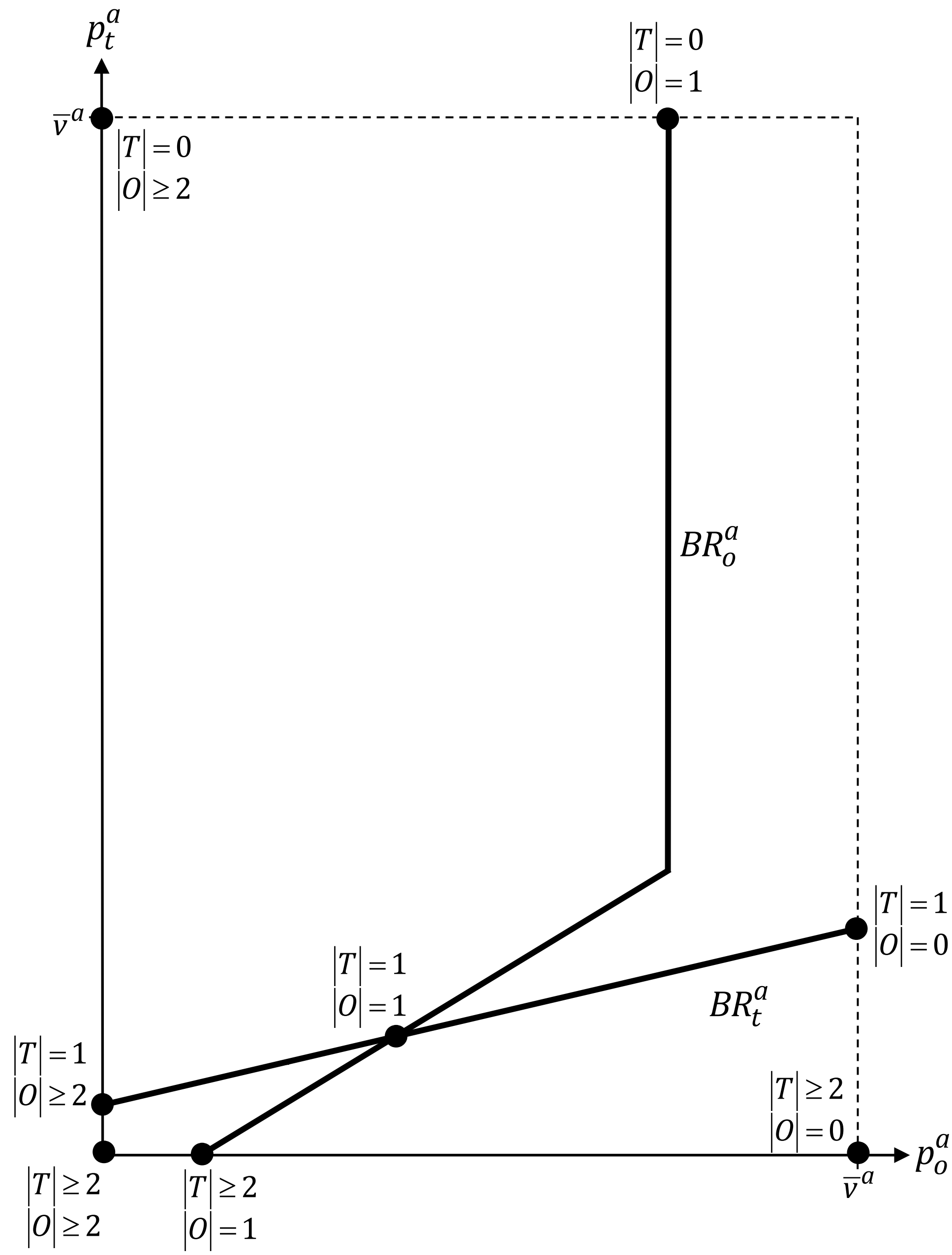

Figure 5: Best-response functions for competition between a traditional and open-access journal. Drawn for the numerical example in which $c^a = 1/2$, $c^r = 0$, and v^a and v^r uniformly distributed on [0,1]. Also serves as a schematic diagram for the general case. For reference, equilibria for all other possible market structures have been identified. The coordinates of the origin are $(c^a + c^r, \max(0, c^a - \pi_{mt}^r))$, reflecting the zero-profit constraint on prices. The price space is not a square because of this origin shift.

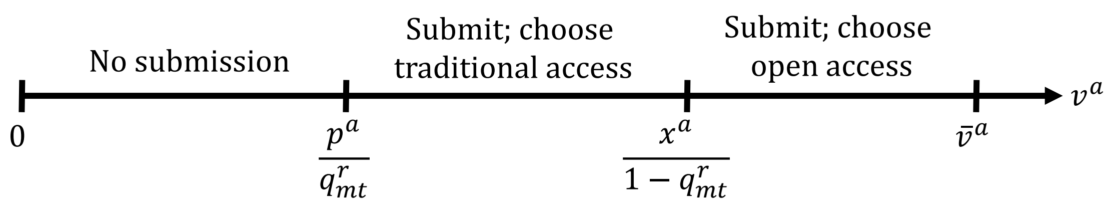

Figure 6: Author's equilibrium continuation strategy when facing a hybrid journal. If all author prices are positive, author values are partitioned into three subintervals. The lowest values do not submit articles, intermediate values submit under traditional access, and the highest values pay the premium for open access. If basic submission is free ($p^a = 0$), then the first subinterval is empty; hence all types submit an article.

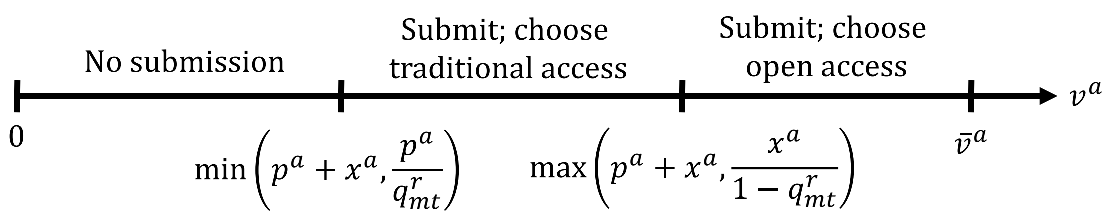

Figure B1: General characterization of author's equilibrium continuation strategy when facing a hybrid journal. Author value per reader partitioned into three subintervals. Author does not submit article for lowest values, submits under traditional access for intermediate values, and pays premium for 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.

Case	Necessary and Sufficient Condition
(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)	$0 = p^a = x^a$

Diagram of author submission strategy

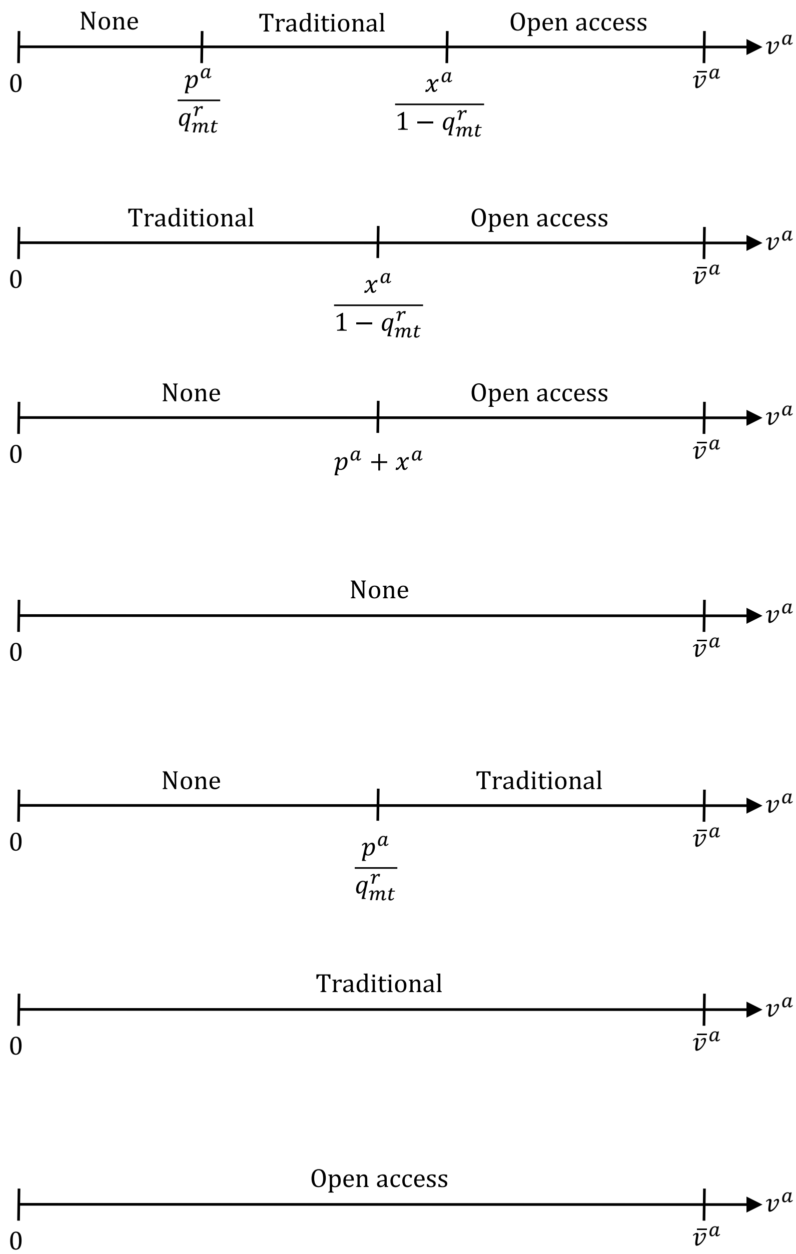

Figure B2: Detailed characterization in specific cases of author's equilibrium continuation strategy when facing a hybrid journal. General characterization leads to even cases depending on which partitions from Figure B1 are empty.

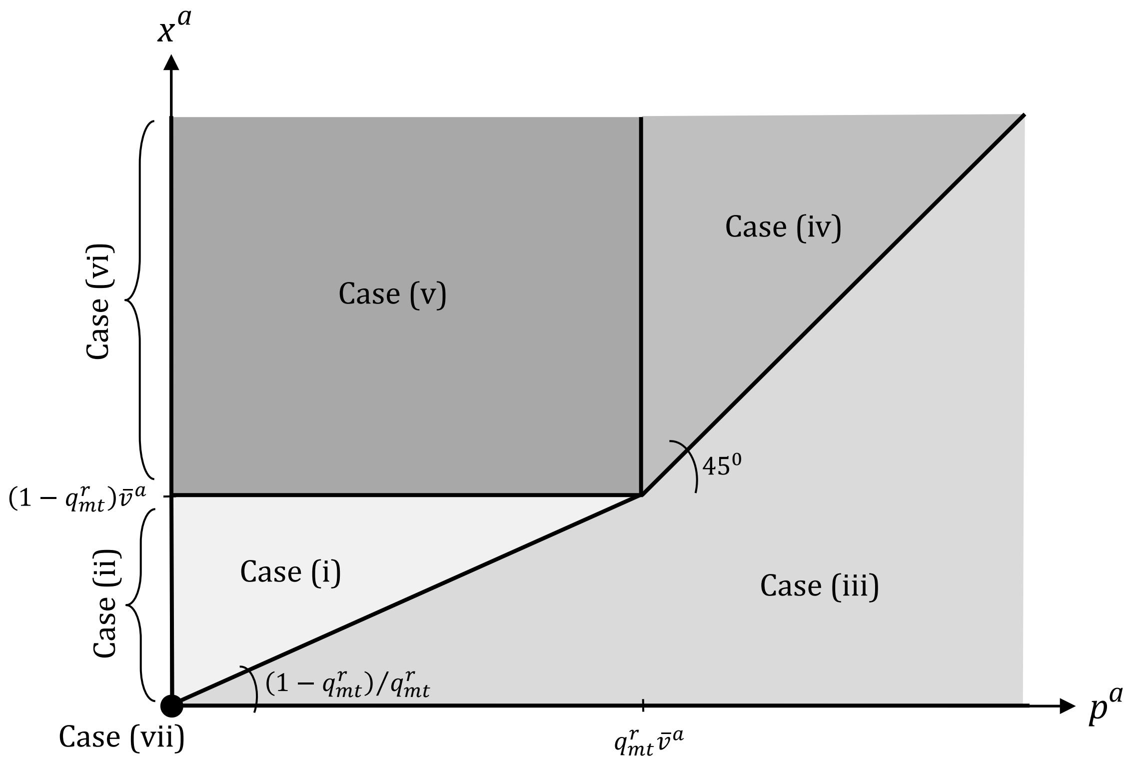

Figure B3: Graph of algebraic conditions from Figure B2. Cases along vertical axis involve zero submission fee: cases (ii) and (vi) are line segments and (vii) is a point.