Academic Journal Prices in a Digital Age: A Two-Sided-Market Model

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June 2006

Abstract: Digital-age technologies promise to revolutionize the market for academic journals as they have other forms of media. We model journals as intermediaries linking authors with readers in a two-sided market. We use the model to study the division of fees between authors and readers under various market structures, ranging from monopoly to free entry. The results help explain why print journals traditionally obtained most of their revenue from subscription fees. The results raise the possibility that digitization may lead to a proliferation of online journals targeting various author types. The paper contributes to the literature on two-sided markets in its analysis of free-entry equilibrium and modeling of product-quality certification.

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

JEL Codes: L14, L82, D40, L31

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Acknowledgments: We thank Mark Armstrong, Lars Stole, and seminar participants at George Washington University, MIT, Santa Clara University, Ruhr-Universität Bochum, Tulane University, the University of Chicago, the University of Göttingen, the ALPSP/OSI/SPARC Meeting (Washington), the American Association for the Advancement of Science Annual Meetings (Washington), the Frankfurt Scientific Symposium, the International Industrial Organization Conference (Chicago), the Third Nordic Conference on Scholarly Communication (Lund), and the ZEW Conference on the Economics of Information and Communication for helpful comments and to Kyle Thomason for excellent research assistance.

1. Introduction

The market for academic journals is in a state of flux. Library subscription fees, the chief source of revenue for commercial academic publishers, have been rising in real terms over the past several decades (McCabe 2002, Dewatripont *et al.* 2006) to the point that commercial journals' prices are an order of magnitude higher than non-profits' (Bergstrom 2001, Dewatripont *et al.* 2006). Consolidation among commercial publishers appears to have contributed to the price increase (McCabe 2002). At the same time, new technologies, including digitization and the Internet, hold out the possibility of revolutionizing academic journals along with all other forms of media. These new technologies will certainly alter the cost structure of academic journals, with ramifications for pricing, market structure, and even the very essence of what academic journals are.

In this paper, we develop a theoretical framework for understanding the impact of the digital revolution on journal prices, quality, and market structure. The key feature of the journals market captured in our framework is its "two-sided" nature. Subscribers on one side of the market benefit from the scholarship of authors on the other side. Conversely, authors benefit from having a large number of readers. Journals serve as intermediaries between the two sides. Drawing on the growing industrial-organization literature on two-sided markets, we develop a model tailored to the case of academic journals.[1] We use the model to understand how the traditional structure of academic journal prices, with zero or low author fees on one side and high subscription fees on the other, might have arisen. We analyze how the change in the structure of journal costs in the digital age may change the structure of journal prices. We study the efficiency and competitive viability of a new model of journal pricing, open access, advocated by a growing number of scholars and librarians. The open-access model turns the traditional pricing model on its head, making articles freely available to readers over the Internet and deriving revenues instead from high author fees. We explore how the market structure of journals may evolve in response to entry and competition. Will one journal emerge that serves as a centralized intermediary between all authors and readers, or will niche journals emerge serving different segments of the market? How does the answer depend on costs and author- and reader-demand conditions?

[1] The literature on two-sided markets includes Ambrus and Argenziano (2005); Armstrong (forthcoming); Baye and Morgan (2001); Caillaud and Jullien (2001, 2003); Evans (2003); Hermalin and Katz (2004); Jeon, Laffont, and Tirole (2004); Laffont *et al.* (2001); Rochet and Tirole (2002, 2003, forthcoming); Schmalensee (2002); and Wright (2004a, 2004b).

To increase the scope of its applicability, our model adopts a broad perspective toward some issues that are difficult to resolve empirically or theoretically. For instance, while there is little doubt that there is considerable inertia in consumer behavior, journal pricing strategy, and journal reputations in the short run, and that this inertia affords journals market power in the short run, it is less clear how much inertia there is in the long run. It is also hard to measure the extent of entry barriers, which include intangible reputational capital and complicated bundling strategies used by incumbent publishers. Therefore, we analyze a variety of different market structures, ranging from monopoly to duopoly to free entry. Which variant applies depends on the adjustment period (short, medium, or long run) the analyst has in mind and the analyst's beliefs about the extent of entry barriers.

We also take a broad perspective toward authors' precise motives in submitting journal articles, adopting several alternative assumptions. One is that authors derive a benefit from each new reader, whether from the "warm glow" of being read or from the career benefits of being widely read, recognized, and cited. In this alternative, from an authors' perspective, high-quality journals are widely-read ones, and authors are willing to pay a heterogenous premium for increased readership. This variant abstracts from article quality for simplicity. Readers derive a heterogeneous benefit purely from the number of articles read. We also analyze an alternative assumption in Section 7.4 that an author does not care directly about the journal's number of readers but only about its reputation. A journal's reputation is given by the average quality of articles published there. Readers benefit from the total quality (number of articles times average quality of article in the journal) of research in the journal. The former variant has the virtue of being simple and being close to the existing literature on two-sided markets so that the results can be easily compared; the latter variant is more complicated but, in incorporating article quality, incorporates a vitally important aspect of the journals market that differentiates it from other markets such as telecommunications or payment systems.

Several key insights emerge from the analysis. One is that a monopoly journal has no inherent reason to favor either authors or readers in its pricing. The monopolist is interested in extracting revenue from all possible sources. One side of the market would obtain relatively favorable prices only if there is a great deal of asymmetry between author and reader benefits or costs. For example, the monopolist may charge low or zero fees (open access) to readers if benefits on the author side of the market are much greater than on the reader side. Conversely, the monopolist may charge low or zero submission fees if the benefits on the reader side dominate those on the author side. Similar reasoning applies to the socially efficient (second-best) prices, even though of course socially efficient prices may be lower on both sides of the market. There is no inherent reason for the social planner to favor authors or readers. The social planner shades prices down for the side of the market that is not too important for revenue (so does not contribute to relaxing the break-even constraint much) and that generates big positive externalities for the other side of the market (typically because it is the low-value side and the other is the high-value side).

Competition changes matters. While readers can subscribe to many journals simultaneously, authors can only publish an article in one. In the parlance of the two-sided-markets literature, authors "singlehome" and readers "multihome." This leads competition to be relatively tougher for authors than for readers: readers cannot freely substitute across journals because each has an effective monopoly over the articles published there. To make the discussion concrete, consider the free-entry equilibrium (we also analyze duopoly competition). If the journal's fixed cost of serving an additional reader (denoted c^R, distinct from the transaction cost of delivering a single article to a single reader, denoted c) is low enough, in equilibrium there is a proliferation of journals that are each targeted to authors of particular types. Different journals may offer different points on the submission-fee/readership-size frontier. In the variant of the model in Section 7.4 that also includes article quality, there may be a further proliferation of journals as different journals may target each individual quality level as well. On the other hand, if c^R is sufficiently high, a few—or in the extreme one—journal may publish all articles, since having few journals economizes on the duplication of fixed reader costs. The pressure of potential entrants keeps the submission fee low, in many instances reducing it to zero. The model thus provides an explanation of why author fees over the previous several decades—essentially a print-journal environment in which c^R is high—have generally been low, a much less important source of revenue than subscription fees. To the extent that new digital technologies can be expected to reduce c^R, one can expect an expansion of entering journals into various price-point/quality niches.

In related literature, the most comprehensive treatment of new policy issues facing the academic-journals market in the digital age is Dewatripoint (2006), which also contains a detailed empirical analysis of pricing trends. Besides our own previous work,[2] the existing theoretical literature on academic journals, in-

[2]McCabe and Snyder (2006) is an ancillary paper that analyzes the alternative modeling as-

cluding McCabe (2004) and Jeon and Menicucci (forthcoming), takes as given that the only source of revenue is library subscription fees, and thus cannot be used to analyze the division of fees across authors and readers that the present paper's two-sided-market model can. Of the papers in the industrial-organization literature on two-sided markets cited in footnote 1, perhaps the two most closely related are Armstrong (forthcoming) and Rochet and Tirole (forthcoming). Both are general analyses of two-sided markets with a broad coverage of many different applications and variants, one of which is relevant for the journals market: the hybrid case of singlehoming on one side of the market and multihoming on the other. Our work differs from the relevant section of these two papers in several respects. There are minor modeling differences among the papers: our specification of costs is more general than Armstrong's; we assume per-reader and per-author fees, whereas Armstrong considers both per-connection and lump-sum fees, etc. More substantively, we analyze three different market structures—monopoly, homogeneous duopoly, and free entry—whereas Rochet and Tirole focus on monopoly and Armstrong considers yet a fourth market structure, differentiated duopoly on a Hotelling line.[3] On a conceptual level, the questions we address are different. The main results of relevance in Armstrong relate to the efficiency of equilibrium as the platforms become less differentiated and to the comparative static effect

sumption of lump-sum prices rather than per-reader or per-article prices assumed here. Equilibria are much harder to characterize in that ancillary paper, and many results have to be stated as possibility results, proved with numerical examples. McCabe and Snyder (2005) sketches the analysis of a model in which talented editors weed out bad papers that are costly for subscribers to read but provide no benefits. The analysis is less general than in the present paper, only analyzing the case of monopoly under the assumption that authors have homogeneous valuations, essentially removing the author side of the market from the analysis.

[3]A technical contribution of our paper is that it is one of the first generalizations of Bertrand competition in the presence of heterogeneous consumers to the two-sided-market context. Caillaud and Jullien (2001, 2003) analyze Bertrand competition for homogeneous consumers. Contemporaneous research by Ambrus and Argenziano (2005) analyze Bertrand competition for heterogeneous agents under Ambrus' (forthcoming) coalitional-rationalizability refinement. Ambrus and Argenziano demonstrate the possibility of profitable asymmetric equilibria. Much of our analysis focuses on symmetric equilibria, in which, as we prove, journals always earn zero profit. We provide an example of an asymmetric equilibrium generating positive profits for two for-profit journals in footnote 9. We provide another example, in Section 7.2, in which competition between a non-profit and a for-profit journal leads to an asymmetric equilibrium. Focusing on symmetric equilibria does not greatly reduce the generality of our analysis since it mainly provides preliminary results later invoked in the analysis of free-entry equilibrium, which is arguably the case of most interest. To our knowledge, ours is one of the first papers to analyze free-entry equilibrium among homogeneous intermediaries in a two-sided-market model.

of moving from per-connection to lump-sum pricing. The main formal results of relevance in Rochet and Tirole relate to the derivation of Lerner indexes. They do outline general principles guiding when low or zero prices emerge on one or the other side of the market, which is a central issue in our analysis.[4] Perhaps the most obvious difference between our work and Armstrong and Rochet and Tirole is that their work does not consider vertical quality differentiation, as we do in the variant in Section 7.4.

The two-sided-market literature has only recently begun to incorporate quality issues, beginning with contemporary research in Lerner and Tirole (2004) and Morrison and White (2004). Lerner and Tirole construct a model in which standard-setting organizations are intermediaries between technology sponsors and end users. Intermediaries obtain perfect signals of the value to end users of submitted technologies and choose whether or not to certify the technologies as being good or bad for end users. Intermediaries are benevolent, differing in the weights they put on the surpluses of the two sides of the market in their objective functions. Our model differs in that certification is not zero-one but is given by the average quality of published articles; our intermediaries are profit-maximizing and can commit to a quality threshold. In Morrison and White (2004), intermediaries are regulators that license banks as being sound or unsound. Regulators in different countries differ in the prior probability that they have a viable screening technology. Their model differs from ours in that their intermediaries are benevolent and do not charge licensing fees. Therefore, the central question in our analysis—the level of access prices on the two sides of the market—is not an issue in their paper.

The paper is structured as follows. Section 2 presents the basic model with articles of homogeneous quality. Sections 3 through 6 analyze the range of market structures from monopoly to duopoly to free entry as well as the second-best social optimum. Section 7 analyzes a number of extensions. Section 7.1 allows journal costs to depend in part on the pricing scheme. In particular, by making articles freely available for download over the Internet, an open-access scheme eliminates the need to process reader accounts and, combined with online distribution, eliminates any fixed costs of serving a reader, c^R. We point out that this cost savings increases the range of parameters for which a for-profit journal, whether

[4]Their "topsy-turvy principle" is that small asymmetries between the two sides of the market will be exaggerated as prices on the low-demand side are further reduced to recruit more members on that side, thereby increasing the revenue that can be extracted from the high-demand side, explaining the widespread prevalence of zero prices in markets such as over-the-air television, yellow pages, etc.

monopoly or competitive, would adopt open access in equilibrium and increases the range of parameters for which open access is socially efficient. In Section 7.2, we make some general points about how the analysis changes if non-profit rather than for-profit journals are considered. The more market power a non-profit journal has, the more flexibility it has to pursue its idiosyncratic objectives, whether it be maximizing readership, maximizing social surplus, or some other objective. We discuss when a non-profit journal can viably pursue its objectives even under stringent competitive conditions of free-entry equilibrium. In Section 7.3, we discuss how to modify the model to allow for the possibility that a journal may derive revenue from external sources such as foundation grants, advertising, and professional-society subsidies. We also briefly discuss how the results change if authors can rely on external sources (their employers or grant funders, for example) to fund submission fees or if readers can rely on external sources (their employers' library, for example) to fund subscription fees. Section 7.4 analyzes the variant of the model in which articles vary in quality and authors care about journal reputation, discussed above. Appendix A contains proofs of the propositions. Appendix B provides an empirical analysis of journal pricing using a panel of over 200 business and economics journals cited in Section 2 as supporting some of the modeling assumptions made there.

2. Model

The model has three types of economic agents: journals, authors, and readers. Journals are intermediaries between authors and readers. Journals acquire articles from authors, bundle them into an issue, and distribute them to subscribing readers. Each article costs the journal c^A to process, including the costs of refereeing, copy editing, typesetting, etc. The cost of distributing the articles to a single reader includes a fixed cost c^R for the bundle of articles in the journal plus a variable cost c per article. The fixed cost c^R includes the cost of servicing the reader's account and any fixed shipping and handling costs. The remaining variable shipping costs, including bandwidth charges for the case of electronic distribution, are embodied in c.

Each author is endowed with a single article.Author i obtains a benefit $b_i^A \in \mathbb{R}$ per reader. This term embodies a number of potential benefits. The author may obtain pure enjoyment from being read by an additional reader. Having more readers also enhances an author's career prospects through better name recognition and increased citations, both used as measures for evaluating author talent in hiring, tenure, and promotion decisions. Assume $b_i^A \geq 0$ is a continuous random variable having distribution function F^A and support $[0, \bar{b}^A]$. The upper bound on the support, $\bar{b}^A$, can be infinite. Let m^A be the mass of authors.

Reader k obtains benefit $b_k^R \in \mathbb{R}$ per article read. This term embodies the benefit the reader obtains from the information contained in the article. The reader can read as many articles as he likes from the journals to which he subscribes. Assume $b_k^R \geq 0$ is a continuous random variable having distribution function F^R and support $[0, \bar{b}^R]$. The upper bound on the support, $\bar{b}^R$, can be infinite. Let m^R be the mass of readers.

Note we have assumed a fair degree of homogeneity. There are no exogeneous differences among journals. They have identical costs. They may differ in quality but only to the extent they publish different numbers of articles or have different numbers of readers, not in the quality of the articles published nor in the value added in selecting or editing them. Authors differ in the benefits they gain from publishing their articles, but their articles provide identical benefits to readers. That is, articles are of a similar quality.[5] Readers differ in the benefits they gain from reading a given article, but having the article read provides the same benefit to an author regardless of who is doing the reading. If the author benefits from the readers' citations, for example, the implicit assumption is that all readers are equally likely to cite a given author's work. In particular, it might be realistic in some settings to assume high-b_i^R readers produce more citations, but for simplicity we do not pursue this extension here. We have also assumed a fair degree of linearity. An author's benefit from having his article read is linear in the number of readers. A reader's benefit is linear in the number of articles he reads.

The benefits authors provide readers and vice versa are externalities because the two sides cannot compensate each other directly for these benefits. Journals are therefore an example of what the literature calls two-sided markets. See Rochet and Tirole (forthcoming) for a discussion and review of the literature. The key implication of the fact that the journals market is "two-sided" is that outcomes will depend on the division of fees across authors and readers, not just on the total.

[5] A natural question arising in this simple model regards why journals exist in the first place. Why do authors not circumvent the intermediary and circulate their articles directly to readers? First, bundling articles in a journal economizes on the fixed cost, c^R, of serving readers. If $c^R > 0$, it would be prohibitively expensive for the infinitesimal authors to circulate their articles directly to the infinitesimal readers. Second, even if $c^R = 0$, it would be straightforward to extend the model to allow journals a role in winnowing the wheat of scholarly articles from the vast chaff of irrelevant information. Third, as modeled in Section 7.4, a function of journals may be to certify article quality.

Contrast this with the result in standard markets, in which one side sells directly to the other, that the burden of a tax does not depend on the party on which the tax is nominally assessed.

Submission fees will be specified on a per-reader basis and subscription fees on a per-article basis, reflecting the long-run-equilibrium perspective that journals can adjust author prices as the number of readers changes and reader prices as the number of articles changes. In particular, we assume journal j charges each author a per-reader submission fee p_j^A times the number of subscribers to journal j, n_j^R, for a total submission fee of $p_j^A n_j^R$. Since all articles are of equal quality, it makes no difference whether p_j^A is taken to be a submission fee or a fee paid conditional on acceptance since all submitted articles are published. The journal charges each reader a per-article subscription fee of p_j^R times the number of articles published by the journal, n_j^A, for a total subscription fee of $p_j^R n_j^A$. The subscription fee is best thought of as a function of the number of articles in the journal rather than the number of articles a subscriber actually reads, although this distinction does not turn out to matter because, with linear benefits and costs of reading per article, a reader who reads any article in a journal reads all of them.

There are several reasons for specifying prices on a per-reader or per-article basis. First, the model's predictions seem to conform to reality. As will be seen in Proposition 3, the equilibrium with free entry of homogeneous journals in a print-journal environment (that is, with $c^R > 0$) involves no author fees and positive subscription fees, which will vary with the number of published articles in equilibrium as the underlying parameters change. This is what we see empirically. Author fees charged by most economics and business journals, for example, are near zero. The fixed-effects regressions in Appendix B show a positive and statistically-significant relationship between library subscription fees for a journal and the number of articles it publishes in a year for a panel of for-profit business and economics journals. This result holds in ordinary least squares as well as in two-stage least squares specifications, the latter instrumenting for articles and citations with lagged values of these variables. Second, as will be discussed further in the next section, when prices are specified on a per-reader or per-article basis, implausible equilibria can be eliminated with a standard refinement—weakly undominated strategies—without having to resort to more esoteric refinements such as Aumann's (1959) strong Nash equilibrium, which are needed to eliminate implausible equilibrium when prices are specified as lump sum. Third, in realistic extensions considered in Section 7.4 in which an author benefits from the journal's reputation as measured by the average quality of articles published there, specification of author fees as per-reader or lump-sum turns out to be equivalent. The alternative assumption of lump-sum prices is analyzed in an ancillary paper, McCabe and Snyder (2006).

We will impose several additional constraints on the model reflecting industry practice. We will constrain prices p_j^A and p_j^R to be non-negative. Journals may subsidize authors and readers, in that prices may be set below marginal cost, but journals cannot make explicit cash transfers to authors or readers.[6] Following industry practice, an author is assumed to be able to publish his article in only one journal, i.e., journals sign exclusive contracts with authors. On the other hand, readers may subscribe to multiple journals.

Players' objective functions are as follows. Journal j's profit is

$$(p_j^A n_j^R)n_j^A + (p_j^R n_j^A)n_j^R - TC(n_j^A, n_j^R) \tag{1}$$

where $TC(n_j^A, n_j^R)$ is the total cost function

$$TC(n_j^A, n_j^R) = c^A n_j^A + c^R n_j^R + c n_j^A n_j^R. \tag{2}$$

If author i submits his article to journal j, he obtains net surplus

$$n_j^R(b_i^A - p_j^A). \tag{3}$$

If reader k subscribes to journal j, he obtains net surplus

$$n_j^A(b_k^R - p_j^R). \tag{4}$$

In the next three sections, we will analyze various market structures for journals—monopoly, duopoly, and free entry—as well as the social optimum. The next section starts with the simplest market structure, monopoly, allowing us to develop the model further in this simple setting.

3. Monopoly Journal

Profit-maximizing monopoly journal j sets prices p_j^A and p_j^R. Author i submits his article to the journal if his surplus given in expression (3) is non-negative, or,

[6]The restriction of cash transfers appears to be nearly universal among scholarly journals. We suspect journals' strong motivation for this restriction is to avoid the appearance of corruption. It would be interesting to develop a broader model in which this restriction arises endogenously, but in this paper it is imposed exogenously.

rearranging, if $b_i^A \geq p_j^A$. Recalling the mass of authors is m^A, author demand for the journal is

$$n_j^A = m^A[1 - F^A(p_j^A)]. \tag{5}$$

Similarly, reader demand for the journal can be shown to equal

$$n_j^R = m^R[1 - F^R(p_j^R)]. \tag{6}$$

Demand equations (5) and (6) implicitly rule out the possibility that the market breaks down as each side of the market anticipates no one on the other side will participate. Constraining authors and readers to play weakly undominated strategies is sufficient to rule out market breakdown and ensure that (5) and (6) uniquely represent demand.[7] We will adopt the refinement of weakly undominated strategies throughout the rest of the paper.

The first-order condition from maximization of journal profit (1) with respect to p_j^A, for example, is

$$\frac{dn_j^A}{dp_j^A} n_j^R (p_j^A + p_j^R) + n_j^A n_j^R - MC^A \frac{dn_j^A}{dp_j^A} = 0, \tag{7}$$

where $MC^A = dTC(n_j^A, n_j^R)/dn_j^A = c^A + cn_j^R$ is the marginal author cost. The first-order condition can be rearranged in the form of a Lerner index:

$$L^A \equiv \frac{n_j^R p_j^A - MC^A}{n_j^R p_j^A} = \frac{1}{|\epsilon_j^A|} - \frac{n_j^A n_j^R p_j^R}{n_j^A n_j^R p_j^A}, \tag{8}$$

where $\epsilon_j^A \equiv (dn_j^A/dp_j^A)(p_j^A/n_j^A)$ is the own-price elasticity of author demand. The Lerner index L^A is defined to be the percentage markup of the total author fee $n_j^R p_j^A$ over marginal cost MC^A. Equation (8) characterizes the monopoly price as long as the constraint $p_j^A \geq 0$ does not bind; if (8) would imply a negative price, then the solution is $p_j^A = 0$. The corresponding first-order condition and expression for the Lerner index for reader price p_j^R are analogous, simply interchanging superscripts.

Equation (8) implies that the journal prices as would a multiproduct monopolist producing complementary goods, here, authors and readers. The journal shades

[7] Given that, for example, author prices are specified as per-reader, it is a weakly dominant strategy for authors to submit to a monopoly journal as long as his net benefit per reader is positive. If no readers subscribe, the author pays nothing so is no worse off than if he did not submit. If a positive measure of readers subscribe, the author gains more from submitting than not.

the submission fee $n_j^R p_j^A$ down somewhat from the single-product Lerner index formula to take account of the effect that increasing the number of articles increases the number of readers. Similar reasoning holds for the subscription fee $n_j^A p_j^R$.[8] The greater is the revenue earned from readers, $n_j^A n_j^R p_j^R$, relative to that earned from authors, $n_j^A n_j^R p_j^A$, the more the journal gains from subsidizing authors to increase reader demand.

Analysis of equations (1) and (8) indicates that a monopoly journal may charge strictly positive prices for both authors and readers. This will indeed be the case if both sides of the market are symmetric or nearly so. Charging positive prices allows the monopolist to extract surplus from both sides of the market. For the monopolist to wish to charge a negative price to one side of the market (observed as a zero price given the non-negativity constraint), the two sides of the market must be sufficiently asymmetric: i.e., the revenue potential of one side of the market must be sufficiently greater than the other. The monopolist would then subsidize the low-value side of the market in order to extract more surplus from the high-value side. Open access will thus only emerge in equilibrium with a monopoly journal if the author side of the market is sufficiently high-value relative to the reader side. If the two sides are perfectly symmetric, a monopolist would never adopt open access. This is true even if readers are costless to serve, $c^R = c = 0$, because of the Internet or other technology.

Most of the comparative-static results for changes in the parameters on equilibrium prices are ambiguous. The exceptions are the derivatives dp_j^A/c^A and dp_j^R/dc^R, which can be unambiguously signed, as the following proposition shows. The proof of Proposition 1 and all subsequent propositions are provided in Appendix A.

Proposition 1. *In equilibrium with a monopoly journal, if the second-order conditions sufficient for a maximum, detailed in the proof, hold, p_j^A is nondecreasing in c^A and p_j^R is nondecreasing in c^R.*

The proof of the proposition sketches some examples that can be used to establish the ambiguity of the other comparative-statics results.

If the author and reader sides of the market are sufficiently asymmetric, then the monopolist may set a zero price on one or the other side, as can be shown

[8]The equilibrium price for the multiproduct monopolist may be higher than for the single-product monopolist because the existence of the complementary good may raise a product's demand. The statements here involve a comparison of structural Lerner-index formulae rather than equilibrium prices.

in examples. Suppose $c^A = c^R = c = 0.1$, $m^A = m^R = 1$, b_i^A is uniformly distributed on $[0, \bar{b}^A]$, and b_k^R is uniformly distributed on $[0, \bar{b}^R]$. Suppose further $\bar{b}^A = \bar{b}^R = 1$. Then the equilibrium monopoly prices are $p_j^A = p_j^R = 0.43$, monopoly profit is 0.13, and social welfare is 0.32. Holding all other parameters constant except for $\bar{b}^A$, the monopoly switches from charging both positive prices to open access (i.e., $p_j^R = 0$) when $\bar{b}^A$ is increased above the threshold of 2.5. Similarly, returning the parameters to their original levels and holding them all constant except for $\bar{b}^R$, the monopoly switches from charging both positive prices to a free-submission policy (i.e., $p_j^A = 0$) when $\bar{b}^R$ is increased above a threshold of 2.5. As Proposition 1 indicates, the lower is c^A, the lower is p_j^A, and so the more willing is the monopolist to adopt free submission. In this numerical example, if c^A is reduced from 0.1 to 0, the threshold value of $\bar{b}^R$ above which the monopoly journal adopts free submission falls from 2.5 to 2. Similarly, if c^A is returned to 0.1 but c^R is reduced from 0.1 to 0 (perhaps capturing Internet distribution), the threshold value of $\bar{b}^A$ above which the monopoly journal adopts open access falls from 2.5 to 2.

4. Social Optimum

In this section, we will analyze the second-best problem for a social planner. The second best maximizes the sum of consumer and producer surplus subject to a break-even constraint for the firm. The Lagrangian associated with this constrained optimization problem is

$$G^A(p_j^A, n_j^R) + G^R(p_j^R, n_j^A) - TC(\hat{n}^A, \hat{n}^R) + \lambda \Pi^m(p_j^A, p_j^R), \tag{9}$$

where $G^A(p_j^A, n_j^R)$ is the gross consumer surplus of authors,

$$G^A(p_j^A, n_j^R) \equiv \int_{p_j^A}^{\infty} n_j^R b \, dF^A(b), \tag{10}$$

$G^R(p_j^R, n_j^A)$ is the gross consumer surplus of readers, defined analogously as in (10), and $\lambda \in \mathbb{R}^+$ is the Lagrange multiplier on the journal's break-even constraint. The first-order condition with respect to the effect of a change in p_j^A on Lagrangian (9) can be rearranged into a Lerner-index formula:

$$L_s^A = \left(\frac{\lambda}{1+\lambda}\right) \left[\frac{1}{|\epsilon_j^A|} - \frac{n_j^A n_j^R p_j^R}{n_j^A n_j^R p_j^A} - \frac{G^R(p_j^R, n_j^A)}{\lambda n_j^A n_j^R p_j^A}\right]. \tag{11}$$

Equation (11) nests both the monopoly case—in the limit as $\lambda \to \infty$, L_s^A approaches the monopoly Lerner index, L^A, in (8)—and the first-best case—in the limit as $\lambda \to 0$, L_s^A approaches $-G^R(p_j^R, n_j^A)/(n_j^A n_j^R p_j^A)$.

Equation (11) is readily interpretable. Ignoring the last term $G^R(p_j^R, n_j^A)/(n_j^A n_j^R p_j^A)$ gives the usual Ramsey pricing formula. The inclusion of the last term reflects the positive externality readers gain from authors that the firm is unable to appropriate. The higher is gross reader surplus $G^R(p_j^R, n_j^A)$ relative to author revenue $n_j^A n_j^R p_j^A$, the greater the relative externality exerted by authors on readers, and the lower the second-best submission fee, resulting in an increase in the number of authors and thus reader surplus.

L_s^R, the Lerner index for the second-best reader fee, is analogous to (11), interchanging superscripts. Because, as can be demonstrated from equation (2), the total cost function exhibits non-decreasing ray average cost, L_s^A and/or L_s^R can be negative. Indeed, if the zero-profit constraint binds, at least one of L_s^A or L_s^R must be non-positive. L_s^A will be negative if relative reader revenue, $(n_j^A n_j^R p_j^R)/(n_j^A n_j^R p_j^A)$, or relative gross reader surplus, $G^R(p_j^R, n_j^A)/(n_j^A n_j^R p_j^A)$, is sufficiently large. Indeed, if either of these terms becomes large enough, L_s^A will fall to the point that the non-negative price constraint, $p_j^A \geq 0$, will begin to bind. Then the second-best submission fee would be zero. Similarly, L_s^R will be negative if relative author revenue or relative gross author surplus is sufficiently large. If these terms are large enough, the constraint $p_j^R \geq 0$ would bind and second-best subscription fee would be zero; i.e., the second best would involve open access. In sum, free submission will be socially efficient if the reader side of the market is important, either in terms of authors' gross consumer surplus or the revenue generated from readers; conversely, open access will be socially efficient if the author side of the market is important.

Return to the numerical example from the previous section in which $c^A = c^R = c = 0.1$, $m^A = m^R = 1$, and b_i^A and b_k^R are uniformly distributed on $[0, 1]$. Prices in the second best are $p_j^A = p_j^R = 0.17$, 60 percent lower than the monopoly prices. Journal profit is zero. Social welfare is 0.57, 78 percent higher than in the monopoly equilibrium. Prices in the first best hit the non-negativity constraint: $p_j^A = p_j^R = 0$. Journal profit in the first best is -0.30, and social welfare is 0.70, more than double that in the monopoly equilibrium. The deadweight loss from a monopoly journal can thus be quite large, even in simple examples.

5. Duopoly Journals

In this section, we analyze the case of two competing journals, $j = 1, 2$, which set prices p_j^A and p_j^R simultaneously. We will assume journals are homogeneous, leading to stringent competition. The case of homogeneous journals is important to analyze for two reasons. First, the analysis complements the monopoly analysis from Section 3, providing the other extremes of a continuum of market structures. The case of moderate competition between two differentiated journals could be expected to fall somewhere in between. Second, while two general-interest journals or two journals in the same subfield may be differentiated by reputation in the short run, it is possible that reputations may evolve over time so that there is less differentiation between them in the long run. Given our interest in understanding long-run outcomes in this paper, and given our uncertainty about how sticky reputations are in the long run, it is worth devoting some attention to the case of stringent competition.

We will focus on symmetric, pure-strategy equilibria of the game between two profit-maximizing journals.[9] Symmetry will mean only that journals choose the same prices; it will not always mean that the journals have the same number of authors and readers ex post. In particular, for some parameters, equilibrium will only be sustainable if all authors coordinate on a single journal. In such cases, there will only be one active journal ex post although journals may have equal ex ante chances of being the active one.

Journal j's reader demand in the symmetric outcome is

$$n_j^R = m^R[1 - F^R(p_j^R)]. \tag{12}$$

There is no exclusivity between journals and readers, so the mass of readers who obtain positive surplus from subscribing to a journal subscribe to both journals.

[9]Examples can be constructed exhibiting asymmetric, pure-strategy equilibria. Suppose authors have unit mass, half of whom have valuation $b_i^A = 1$ and half $b_i^A = 0$. Similarly, suppose readers have unit mass, half of whom have valuation $b_k^R = 1$ and half $b_k^R = 0$. Supoose $c^A = c^R = c = 0$. There is an equilibrium in which journal 1 charges $p_1^A = 1/2$ and $p_1^R = 0$ and journal 2 charges $p_2^A = 0$ and $p_2^R = 1/2$, yielding positive profit $1/2$ for each journal. The fact that journals adopt free submission and/or open access in this asymmetric equilibrium does not appear to be generic. Only under non-generic conditions on the distributions and parameters would the open-access journal's author price be a best response to the closed-access journal's prices and vice versa, and the journals earn equal profits at these prices. If one of the two firms is a non-profit as in Section 7.2, asymmetric, pure-strategy equilibria can arise generically since the journals need no longer to earn equal profits for the outcome to be stable. Symmetric, mixed-strategy equilibria may be possible if $c^R = 0$, with a journal's strategy being a probability distribution over the locus of price vectors yielding zero expected profit.

Aggregate author demand across journals in a symmetric outcome is

$$n_1^A + n_2^A = m^A[1 - F^A(p_j^A)]. \tag{13}$$

While readers can subscribe to multiple journals, authors must choose a single journal to which to submit. Authors singlehome and readers multihome in the parlance of the two-sided-markets literature. Total author demand in a symmetric outcome given in equation (13) is therefore determined by the number of authors willing to submit an article to any journal. Authors are indifferent between submitting to one journal or the other in a symmetric equilibrium because submission fees are the same and both journals will have the same number of readers. Thus, the division of authors across the two journals is not pinned down by authors' objective functions. The division will either be pinned down by other equilibrium considerations—for example, for a journal to break even at equilibrium prices may require all authors to coordinate on one or the other journal ex post—or, if not, there will be a continuum of divisions including the symmetric division $n_1^A = n_2^A$. In an outcome with asymmetric prices (important to consider when one journal deviates from a symmetric equilibrium), unless one journal has both lower author and reader prices and gets all author and reader demand, author demand is complicated because authors will trade off the benefit of low price versus higher readership, and this tradeoff will vary across authors depending on their value of b_i^A.[10] Reader demand in an asymmetric outcome is still simply given by (12) because readers can subscribe to both journals and make subscription decisions across journals independently.

Since journals are homogeneous and compete in prices, equilibrium will be reminiscent of the standard Bertrand duopoly game. Our model differs from the standard Bertrand game in two ways. First, firms set two prices rather than just one. Second, our cost structure is more complicated. Rather than just being a constant, marginal author cost, for example, is $MC^A = c^A + cn_j^R$, independent of n_j^A but increasing in n_j^R. These two differences complicate the analysis relative to the standard Bertrand game. Our results can thus be regarded as a nontrivial

[10] Formally, author demand in an asymmetric-price outcome, taking the case of say journal 1, is

$$n_1^A = \begin{cases} m^A\left[1 - F^A\left(\max\left\{p_1^A, \dfrac{[1-F^R(p_1^R)]p_1^A - [1-F^R(p_2^R)]p_2^A}{F^R(p_2^R) - F^R(p_1^R)}\right\}\right)\right] & p_1^R < p_2^R \\ m^A F^A\left(\dfrac{[1-F^R(p_2^R)]p_2^A - [1-F^R(p_1^R)]p_1^A}{F^R(p_1^R) - F^R(p_2^R)}\right) & p_1^R \geq p_2^R. \end{cases}$$

extension of the standard Bertrand results to the case of a two-sided market. We will state the main proposition characterizing competitive equilibria for reference first, and then go on to discuss the intuition behind the proposition.

Proposition 2. *In all symmetric, pure-strategy equilibria with two competing journals $j = 1, 2$, each journal earns zero profit. To further characterize symmetric, pure-strategy equilibria, there are three cases to consider.*

Case (i): $c^R > 0$. If there exists an implicit solution for p_j^R in

$$m^R[1 - F^R(p_j^R)][m^A(p_j^R - c) - c^R] - m^A c^A = 0, \tag{14}$$

then there exists a unique symmetric, pure-strategy equilibrium, in which $p_j^{A*} = 0$, p_j^{R*} is given by the lowest implicit solution for p_j^R in (14), and one journal obtains all of the submissions. If there is no implicit solution for p_j^R in (14), then all symmetric, pure-strategy equilibria are trivial: there is a continuum of them involving sufficiently high subscription fees that no readers subscribe.

Case (ii): $c^R = 0$ and $\max(c^A, c) > 0$. There exists a symmetric, pure-strategy equilibrium involving open access that is nontrivial (i.e., involves positive author and reader demand) if and only if

$$c + \frac{c^A}{m^R} \in \left[\max_{x \in [0, \bar{b}^R]} K(x) + c, \bar{b}^A \right), \tag{15}$$

where

$$K(x) \equiv \frac{[1 - F^R(x)]x}{F^R(x)}. \tag{16}$$

Prices satisfy $p_j^{A*} = c + c^A/m^R$ and $p_j^{R*} = 0$ in this equilibrium.

Case (iii): $c^A = c^R = c = 0$. The unique equilibrium involves open submission and open access. Equilibrium prices are $p_j^{A*} = p_j^{R*} = 0$.

As in the standard Bertrand duopoly game, all symmetric equilibria involve zero profit. In any outcome with symmetric prices ($p_j^A = p^A$ and $p_j^R = p^R$ for $j = 1, 2$) in which some journal j earns positive profit ($\Pi_j > 0$), it can be shown that j earns a positive margin on each author: $\Pi_j = n_j^A[n_j^R(p^A + p^R - c) - c^A] - c^R n_j^R > 0$, implying that the marginal profit per author is $n_j^R(p^A + p^R - c) - c^A > 0$. Thus, a journal has an incentive to steal authors from its competitor. If $p^A > 0$, a journal can steal authors directly by undercutting author price p^A slightly. If $p^A = 0$, a journal cannot undercut p^A since negative prices are not allowed but can steal authors indirectly by undercutting the reader price p^R slightly, increasing its subscriber base and thus making the journal more attractive to authors.

In case (i) of Proposition 2, where $c^R > 0$, journals adopt open submission but not open access. To see this result, note that, there is a sense in which journals compete less aggressively for readers than authors. Readers' subscription decisions are independent across journals because they can subscribe to both.[11] Authors must substitute between journals because authors submit to one journal exclusively. The softer competition for readers together with the positive fixed cost of serving them ($c^R > 0$) leads to high reader prices and low author prices in case (i). Even though it earns zero profit, a journal still earns a positive margin on each author since $\Pi_j = n_j^A[n_j^R(p^A + p^R - c) - c^A] - c^R n_j^R = 0$ implies the author markup is $n_j^R(p^A + p^R - c) - c^A = c^R n_j^R / n_j^A$, which is positive if $c^R, n_j^R, n_j^A > 0$. Thus, journals have an incentive to undercut the author price unless $p^A = 0$, at which point undercutting is prevented by the non-negative price constraint.

According to equation (14), p_j^{R*} is the lowest price that provides a journal with non-negative profit given all authors submit to it. It is essential for p_j^{R*} to be the lowest such price, and for all authors to end up submitting to the same journal. Otherwise, there would be an incentive for a journal that did not serve 100 percent of the authors to undercut p_j^{R*} slightly since this would increase its readership, make it relatively more attractive to authors than its competitor, and allow it to steal all its competitor's authors. Given that, as discussed in the previous paragraph, the profit margin is positive on authors when profits are non-negative, the journal would have an incentive to deviate in this way to gain more authors. If at $p_j^A = 0$, a journal cannot earn non-negative profit for any p_j^R even if it serves all of the authors, then the entire journal market shuts down.

If $c^R = 0$ and $\max(c^A, c) > 0$ as in case (ii) of Proposition 2, then there are opposing effects which make the determination of whether open access emerges in equilibrium subtle. On the one hand, journals tend to compete more aggressively for authors than readers, as mentioned, leading to lower author prices and higher reader prices. On the other hand, since $c^R = 0$, marginal author cost may be

[11] A journal's reader demand would depend on the other journal's price in the presence of income effects. McCabe (2004) generates income effects by assuming a library has a fixed budget to divide among journals. Depending on where journals fall on the quality spectrum relative to each other, the cross-price elasticity between journals may be positive as an increase in one's subscription fee depletes the budget that can be spent on the other. See Nevo, Rubinfeld, and McCabe (2005) for further discussion.

higher than marginal reader cost, leading to higher author prices and lower reader prices. To streamline the discussion, ignore for the moment the condition in (15) that $c + c^A/m^R < \bar{b}^A$, which is merely there to ensure that the equilibrium is nontrivial, and focus on the condition that c^A/m^R is sufficiently high. *Ceteris paribus*, the higher is c^A, the costlier it is to serve authors relative to readers and the more likely open access emerges in equilibrium. *Ceteris paribus*, the lower is m^R, the lower the revenue that can be earned by undercutting a rival's author price and stealing its authors, and thus, again, the more likely open access emerges in equilibrium.

Although the condition under which open access emerges in equilibrium in case (ii) of Proposition 2 looks complicated, it often reduces to a simple expression after specifying the functional forms of the distributions. For example, if b_k^R is uniformly distributed on $[0, \bar{b}^R]$, then the condition reduces to $c^A/m^R \in [\bar{b}^R, \bar{b}^A - c)$. If b_k^R is exponentially distributed with mean $1/\mu$, then the condition reduces to $c^A/m^R \in [1/\mu, \bar{b}^A - c)$. In either example, open access is more likely to emerge the lower are the reader-demand parameters ($\bar{b}^R$ and m^R in the uniform case and $1/\mu$ and m^R in the exponential case), the higher is the author fixed cost (c^A), and the lower is the per-transaction cost (c).

Of course, if costs are zero as in case (iii) of Proposition 2, then all prices are zero in the unique equilibrium. Journals adopt open submission and open access.

Return to the numerical example from Sections 3 and 4 in which $c^A = c^R = c = 0.1$, $m^A = m^R = 1$, and b_i^A and b_k^R are uniformly distributed on $[0, 1]$. The parametric assumptions put us in case (i) of Proposition 2. Prices in the symmetric duopoly equilibrium are $p_j^A = 0$ and $p_j^R = 0.36$. Both prices are below their monopoly levels of 0.43. The submission fee is below and the subscription fee is above the second best. Social welfare is close to the second best, 0.53 compared to 0.57. One journal, which earns zero profit, ends up serving all authors and readers ex post.

6. Free Entry

In this section, we will analyze free-entry equilibrium. The analysis is important because entry barriers in the long run may be relatively low compared to other industries. Reputational capital and the complicated bundling strategies of incumbent publishers are perhaps the most substantial barriers (Dewatripont *et al.*

2006).[12] We do not need to take a position here on how much inertia there is in reputations or how much entry is impaired by incumbent bundling—we have analyzed the monopoly case as well already—but observe that there is enough evidence of possible long-run movements that the case of free entry is at least worth considering. Perhaps the strongest argument for considering free entry is the evidence of considerable recent entry in the market for economics and business journals.[13]

We will modify the model to allow for an unlimited number of potential entrants with no fixed cost of entry, although, as before, they may continue to have fixed costs c^A of serving authors and c^R of serving readers. A free-entry equilibrium is an author/reader price pair for each journal such that no active journal can increase its profit and no potential entrant can earn positive profit by deviating to some other prices. Let $j = 1, \ldots, J$ index journals.

With free entry, competition to sign up authors is even more intense than it was in Section 5 with duopoly. There are circumstances in which the free-entry equilibrium involves niche journals catering to individual types of author, providing the type's desired balance between low submission fees on the one hand and low subscription fees/high readership on the other. Such equilibria arise when there are no economies of scale in bundling articles together. Economies of scale in bundling articles arise when $c^R > 0$: fixing the number of articles a reader reads, the fewer journals the articles are divided among, the fewer times the fixed reader cost c^R needs to be expended. Indeed, if $c^R > 0$, the free-entry equilibrium involves one active journal that signs up all authors with free submission, similar to the duopoly equilibrium.

Proposition 3. *In all free-entry equilibria, each journal earns zero profit. To further characterize equilibria, there are three cases to consider.*

Case (i): $c^R > 0$. *If there exists an implicit solution for* p_j^R *in (14), then in the free-entry equilibrium* $p_j^{A*} = 0$, p_j^{R*} *is given by the lowest implicit solution for* p_j^R *in (14), and one journal obtains all of the submissions. If there is no implicit solution for* p_j^R *in (14), then there is no free-entry journal market.*

[12]Even if it is argued that other capital requirements are substantial, external sources of revenue, discussed in Section 7.3, may be available to subsidize entry.

[13]The Berkeley Electronic Press has created twelve new series; the American Economic Association is developing four new field journals; the *Journal of the European Economic Association* was created by a wholesale movement of editors from the *European Economic Review* after a dispute with the publisher; McCabe and Snyder (2006) document 22 new, refereed, open-access journals in the fields.

Case (ii): $c^R = 0$ *and* $\max(c^A, c) > 0$. *There is a continuum of journals, with each author type* b_i^A *served by a different journal. Prices* $p^A(b_i^A)$ *and* $p^R(b_i^A)$ *maximize the gross surplus of author type* b_i^A *subject to a break-even constraint for the journal, leading to the following subscription price:*

$$p^R(b_i^A) = \begin{cases} \underset{p_j^R}{\text{argmax}} \left\{[1 - F^R(p_j^R)](b_i^A + p_j^R - c)\right\} \\ \text{subject to } p_j^R \in \left[0, \dfrac{c^A}{m^R[1 - F^R(p_j^R)]} + c\right]. \end{cases} \tag{17}$$

Case (iii): $c^A = c^R = c = 0$. *The unique equilibrium prices for active journals are* $p_j^{A*} = p_j^{R*} = 0$.

Case (iii) is essentially nested in case (ii) except for the technicality that there does not have to be a continuum of journals in case (iii), although there may be.

Return to the numerical example from Sections 3 through 5 in which $c^A = c^R = c = 0.1$, $m^A = m^R = 1$, and b_i^A and b_k^R are uniformly distributed on $[0, 1]$. The parametric assumptions put us in case (i) of Proposition 3. The free-entry equilibrium is the same as the duopoly equilibrium in this example. The equilibrium prices charged by the journal that serves all authors and readers ex post are $p_j^A = 0$ and $p_j^R = 0.36$. If all the parameters are kept the same but c^R is reduced from 0.1 to 0, then case (ii) applies. A continuum of journals operates with equilibrium prices given in Figure 1. The submission fee is higher for journals serving higher-b_i^A authors, balanced by lower subscription fees and higher readerships. For journals serving authors with valuations $b_i^A = 0.1$ and above, there is open access for readers, since author benefits are sufficiently high that they are willing to pay higher submission fees in exchange for the widest possible readership.

7. Extensions

In this section, we will extend the basic analysis in several directions to try to capture some further institutional details of the journal market in practice.

7.1. Endogenous Reader Cost

The analysis so far has taken the cost structure as given. In practice, costs may depend on the pricing regime. In particular, open access frees the journal from

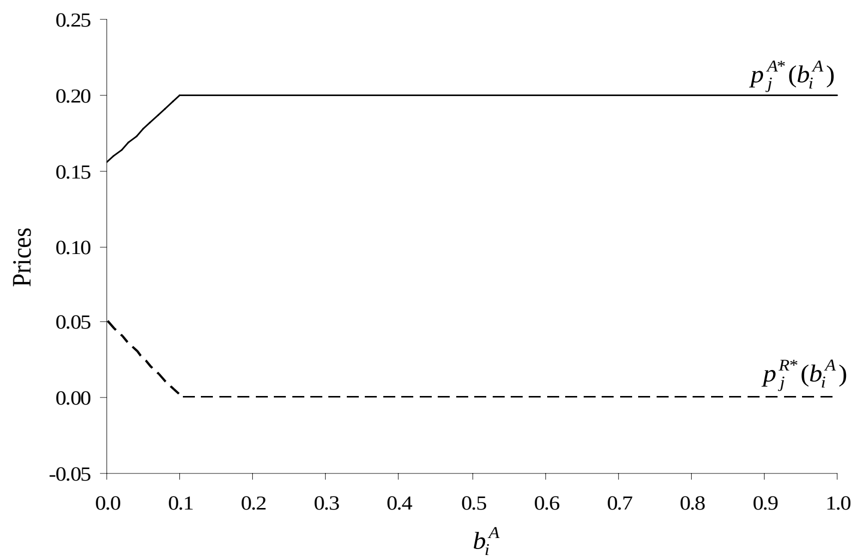

Figure 1: Free-entry equilibrium in numerical example with $c^A = c = 0.1$, $c^R = 0$, b_i^A and b_k^R uniformly distributed on $[0,1]$, and $m^A = m^R = 1$.

having to keep track of readers and process their accounts, leading to lower reader costs. Indeed, in an online-journal environment, open access can eliminate fixed reader costs entirely (in a print-journal environment, delivering the physical copy to the reader may still involve a fixed cost).

We will model the possibility that open access reduces fixed reader costs in the following way. We will continue to take cost parameters c^A and c as given but suppose that the fixed reader cost depends on the pricing regime, equaling $c^R > 0$ if $p_j^R > 0$ and 0 if $p_j^R = 0$. That is, the journal has to pay the fixed cost of creating and processing a reader's account if it wants to collect fees from him. This specification does not rule out the possibility that Internet distribution involves bandwidth costs, which would appear as a positive cost per download $c > 0$ independent of the number of readers who are doing downloading.

It is clear that endogenizing costs in this way increases the range of parameters for which a monopoly would adopt open access, the range of parameters for which the second best involves open access, and the range of parameters for which equilibrium with competitive journals involves open access. To derive formal conditions for the competition result, refer back to Proposition 2. Cases (ii) and (iii) are not relevant since c^R is already taken to be 0, so there is no scope for open access to reduce the fixed reader cost. The relevant case with $c^R > 0$ is (i). In this case, the proposition states that if costs are exogenous, the competitive equilibrium always involves closed access. The next proposition states that for a range of parameters, the cost savings associated with open access would be enough to switch the equilibrium from closed to open access if costs are endogenous as modeled in this section.

Proposition 4. *Suppose there exists an implicit solution for p_j^R in equation (14). Suppose adopting open access reduces the fixed reader costs from $c^R > 0$ to 0. The equilibrium with two competing journals involves open access if and only if*

$$\frac{c^A + cm^R}{\bar{b}^A m^R} < F^R(p_j^{R*}), \tag{18}$$

where p_j^{R*} is the lowest implicit solution to (14).

According to the proposition, endogenizing cost may have a substantial effect on the propensity to adopt open access. For example, if authors and readers have unit mass and their benefits b_i^A and b_k^R are uniformly distributed on $[0, 1]$, then it can be shown that the competitive equilibrium always involves open access for any cost parameters for which the equilibrium exists. This is not to suggest that open access always emerges in equilibrium. The preceding example implicitly involved symmetric author and reader sides of the market. Decreasing the importance of the author side of the market relative to the reader side by taking $\bar{b}^A \to 0$ while keeping the other parameters constant, the left-hand side of (18) increases without bound while the right-hand side is bounded by 1. For small enough $\bar{b}^A$, therefore, condition (18) is eventually violated and closed access rather than open access would emerge in equilibrium.

To the extent that most subscriptions are mediated through libraries, the preceding discussion may exaggerate the cost savings from open access. Journals may only need to pay the fixed cost of processing each library's account rather than the hundreds of readers the library may represent. However, open access may still lead to some cost savings, even if small, eliminating the need to negotiate with each library over price as is done by several commercial publishers and eliminating the cost of processing each library's account. Further, open access may be more convenient for readers, saving them from having to pass through login screens or library gateways. This additional convenience benefit could be modeled along the lines of reader-cost savings.

7.2. Non-Profit Journals

The paper has so far considered profit-maximizing journals. This section takes up the case of non-profit journals, an important case to consider because non-profits make up a substantial portion of the journal market, most notably professional-association journals. The case is more complicated because non-profits may have a variety of different possible objective functions, but we can draw out some of the implications of our analysis so far and can make some additional general points.

Consider the case in which the non-profit journal is a monopolist. Assuming the journal's objective is to maximize social surplus subject to a break-even constraint, then the equilibrium would be equivalent to the second-best social optimum, and the analysis of Section 4 would apply. Other possibilities include that the journal is dedicated to open-access and either maximizes profit or social surplus subject to this constraint. The Public Library of Science (PLoS) journals in biomedicine, founded by Nobel-prize-winner Harold Varmus, may fit this model.

One must be careful to distinguish between the profit and non-profit cases to understand the effect of monopoly power on the pricing regime. In the case of a for-profit monopolist, its monopoly power can generally be expected to result in higher markups compared to the competitive case and thus fewer cases in which a free-submission regime on the one hand or an open-access regime on the other might be observed. Monopoly power for a non-profit will likely have the opposite effect. The non-profit can use monopoly rents to subsidize its particular objectives, whether surplus maximization, zero prices on one or the other side of the market, etc. If, for example, the non-profit journal is interested in promoting open access, it can use its monopoly rents to subsidize low subscription fees. Competitive pressures may reduce the journal's freedom to pursue particular objectives.

To be more concrete about the effect of competition on the viability of certain non-profit objectives, take the case in which journal 1 is a non-profit journal dedicated to open access, modeled assuming journal 1 has lexicographic preferences over reader and author access, implying that it maximizes author surplus subject to an open-access constraint ($p_1^R = 0$) and a break-even constraint. The same analysis would apply to other specifications of journal 1's objective function. Suppose journal 1 competes against profit-maximizing journal 2. Suppose, consistent with Section 5, that the two journals are homogeneous in the sense of serving the same market of authors and readers and sharing the same cost parameters c^A, c^R, and c.

Proposition 2 serves to frame the analysis. In any case open access emerges in competive equilibrium between two profit-maximizing journals, a non-profit journal committed to open access would be competitively viable. Thus, if either, first, journal production is costless (as in case (iii) of Proposition 2) or, second, $c^R = 0$ and $\max(c^A, c) > 0$ (as in case (ii) of the proposition) and condition (15) holds, then a non-profit firm dedicated to open access would be competitively viable. On the other hand, examples can be constructed in which the symmetric equilibrium of the game between two profit-maximizing journals does not involve open access yet in the present setting open-access journal 1 could survive alongside a profit-maximixing journal 2.

To provide such an example (generic in that the same properties arise for small perturbations of the parameters), suppose that there are two types of author, one type with low benefit $b_i^A = 0$ and one with high benefit $b_i^A = \bar{b}^A$. Suppose each has the same mass equal to 1/2, so $m^A = 1$. Suppose the unit mass of readers have benefits b_k^R uniformly distributed on $[0, 1]$. Suppose $c^A = c = 0$ and $c^R > 0$. These parametric assumptions would put us in case (i) of Proposition 2, implying that the symmetric equilibrium between two profit-maximizing journals would not involve open access. Indeed, it would involve the opposite, open submission ($p_j^A = 0$).

In the setting in which non-profit, open-access journal 1 competes alongside profit-maximizing journal 2, journal 1 sets $p_1^R = 0$ and sets a positive p_1^A to cover its costs. The journal specializes in serving the segment of high-benefit authors who are willing to pay a positive price to have a larger number of readers. The lowest price it can charge authors and still break even is $p_1^A = 2c^R$. Profit-maximizing journal 2 specializes in serving the low-benefit authors. It makes no direct profit on these authors since they are not willing to pay a positive price, but uses them to attract readers who can be charged a positive price. Given the parametric and functional form assumptions, journal 2's profit function can be written $(1 - p_2^R)(p_2^R/2 - c^R)$, which is maximized for $p_2^A = 1/2 - c^R$, yielding profit $(1 - 2c^R)^2/8$. This outcome is an equilibrium if high-benefit authors weakly prefer to submit to journal 1 rather than journal 2: $n_1^R(\bar{b}^A - p_1^A) \geq n_2^R(\bar{b}^A - p_2^A)$, implying, after substituting equilibrium prices and quantities and rearranging, $\bar{b}^A \geq 4c^R/(1 + 2c^R)$.

7.3. External Revenue Source

The analysis has assumed that the journal's only revenue source is author and reader fees. In practice, journals sometimes gain additional revenue from a variety of sources including revenue from advertising, registration fees for affiliated conferences set above cost, discriminatory fees charged to non-scholar practitioners, a subsidy from the sponsoring society or host institution, or a grant from a foundation.[14]

We can model this external revenue simply by supposing that journal j has a lump-sum subsidy S_j that it can use to fund operations. It is immediate that this subsidy does not affect equilibrium with profit-maximizing journals for any market structure—monopoly, duopoly, or free entry—because lump sums will not affect their marginal decisions.

A subsidy may affect the second best (or equivalently a non-profit monopoly journal dedicated to maximizing social welfare) and may affect the viability of a non-profit journal dedicated to open access in competition with a profit-maximizing journal studied in the previous section. Consider the second best, discussed in Section 4. The provision of subsidy S_j has the effect of reducing the equilibrium value of the multiplier λ on the break-even constraint which appears in the Lerner index formula (11). Under appropriate second-order conditions, a reduction in λ will reduce both p_j^A and p_j^R, increasing the range of parameters for which there is open access in the second best. Consider the question discussed in Section 7.2 of the viability of a non-profit journal dedicated to open access in competition against a profit-maximizing journal. The provision of a subsidy to the non-profit journal will clearly increase the range of parameters for which it is viable.

External sources of revenue may change the game for other players in the market—authors and readers—as well. To the extent that an author can rely on his home institution or grant funder to pay part of the submission fee, his marginal rate of substitution between readership and fees reflected in b_i^A will increase. If the funder can also dictate the journal to which the author must submit his article, then our original model applies with the parameters on the authors' side reinterpreted as reflecting the funders' valuations.[15] To the extent that a reader can rely on his home institution's library to pay subscription fees, again, the reader's parameters need to be reinterpreted as an aggregation of the underlying demand of the library's patrons.

[14]Some of these sources are more important in fields other than business and economics, but even here they are present in some cases (the *American Economic Review* accepts some advertising, the *Journal of Investment Management* uses conference registration fees to subsidize journal operations, *Economics Bulletin* relies on in-house computer support from its host university, etc.).

[15]This possibility is of current policy interest, with at least 23 major international funding organizations providing line items for increased submission fees according to the website of open-access publisher BioMed Central, www.biomedcentral.com (downloaded May 30, 2006) and with organizations such as the U.S. National Institutes of Health debating whether funded authors should be required to submit to open-access journals.

7.4. Quality Certification

We have so far modeled quality considerations in a relatively spare way. From the authors' perspective, a high-quality journal is a widely read one. From the readers' perspective, a high-quality journal contains many articles. The spare model provides a useful start because it connects with much of the existing literature on two-sided markets and provides a simple setting to fix basic ideas. However, a richer model is needed to capture further quality considerations that are important for journals. Research is not homogeneous; some articles are better than others. Given articles are of heterogeneous quality, some mechanism is needed to certify quality. Readers can use this information to economize on reading time by focusing on the best research or to help weigh the merits of different evidence and methodologies. Employers can use this information to help judge author talent in hiring, tenure, and promotion decisions. Journals provide this certification mechanism. Quality certification is more important for journals than many of the other markets to which the two-sided-market model has been applied, including telecommunications and credit cards.

In this section, we will modify the model used so far by having articles differ in quality, by having authors benefit from publishing in a high-reputation journal—where reputation is measured by the average quality of articles published in equilibrium—and by having readers benefit from the aggregate quality of articles in the journal. Formally, suppose author i is endowed with an article of quality $q_i \in [0, \bar{q}]$. Author i derives net surplus $b_i^A Q_j - n_j^R p_j^A$ from publishing in journal j, where Q_j is the average quality of articles published in journal j, which we will sometimes refer to as the journal's reputation. The model thus departs from the stark assumption that authors care about the number of readers for the stark assumption that authors care about a certification benefit independent of the number of readers. In practice, authors may care about both, but considering each separately simplifies the analysis. Assuming authors care about certification independent of the number of readers can be justified by assuming that the certification appears on the author's curriculum vitae, and the number of people reading the author's curriculum vitae may be independent of the number of people reading the journals listed there. Assume b_i^A and q_i are random variables with joint distribution $F^A(b_i^A, q_i)$. Reader k's net surplus from journal j is $n_j^A(b_k^R Q_j - p_k^R)$. Readers benefit from the total quality of research in journal j, equal to the number of articles n_j^A times average quality per article Q_j. As before, b_k^R is distributed according to $F^R(b_k^R)$. Also, as before, we take author prices to be per-reader (now that authors' benefits are independent of the number of readers, this assumption no longer makes a difference, although we maintain the accounting convention to preserve the notation from before) and take reader prices to be per-article. Journals commit to a quality standard $\hat{q}_j$, accepting a submitted article if and only if $q_i \geq \hat{q}_j$.

In the subsequent analysis, we will briefly outline some of the relevant calculations in the case of monopoly and duopoly but spend most of the time with a formal characterization of the free-entry equilibrium since this is the setting in which we might expect to find the most interesting results with respect to the entry of journals of varying reputations and the competition among them.

First, consider the case in which journal j is a monopoly. Given a quality standard $\hat{q}_j$, the average quality of articles published in the journal implicitly solves

$$Q_j^m = \frac{\displaystyle\int_{\hat{q}_j}^{\bar{q}} \int_{\hat{b}_j}^{\bar{b}^A} q_i \, dF^A(b_i^A, q_i)}{\displaystyle\int_{\hat{q}_j}^{\bar{q}} \int_{\hat{b}_j}^{\bar{b}^A} dF^A(b_i^A, q_i)}, \tag{19}$$

where $\hat{b}_j = n_j^R p_j^A / Q_j^m$ is the valuation of the marginal author (among those whose quality meets the journal's standard) who is indifferent between submitting and not. Comparative statics results are generally ambiguous. Consider the affect of an increse in the quality standard on the subscription price, $\partial p_j^R / \partial \hat{q}_j$. An increase in $\hat{q}_j$ increases average article quality Q_j by cutting off more of the lower tail of articles. This may increase or decrease p_j^R depending on the elasticity of reader demand with respect to Q_j, which in turn depends on $F^R(b_k^R)$. An increase in Q_j also affects n_j^A. The direction is ambiguous: fewer authors are eligible for publication, but more authors with high q_i but low b_i^A may be induced to submit because of the journal's higher reputation. The change in n_j^A will have an indirect effect on p_j^R since the marginal revenue from readers depends on n_j^A.

Turning to the duopoly case, suppose there are two journals with exogenously given quality standards $\hat{q}_1 > \hat{q}_2$, so 1 is the higher prestige journal of the two. Average quality for each journal is

$$Q_1 = \frac{\displaystyle\int_{\hat{q}_1}^{\bar{q}} \int_{\max(\hat{b}_1, \hat{b}_{12})}^{\bar{b}^A} q_i \, dF^A(b_i^A, q_i)}{\displaystyle\int_{\hat{q}_j}^{\bar{q}} \int_{\max(\hat{b}_1, \hat{b}_{12})}^{\bar{b}^A} dF^A(b_i^A, q_i)} \tag{20}$$

$$Q_2 = \frac{\int_0^{\hat{q}_2} \int_{\hat{b}_2}^{\bar{b}^A} q_i \, dF^A(b_i^A, q_i) + \int_{\hat{q}_2}^{\bar{q}} \int_{\hat{b}_2}^{\hat{b}_{12}} q_i \, dF^A(b_i^A, q_i)}{\int_0^{\hat{q}_2} \int_{\hat{b}_2}^{\bar{b}^A} dF^A(b_i^A, q_i) + \int_{\hat{q}_2}^{\bar{q}} \int_{\hat{b}_2}^{\hat{b}_{12}} dF^A(b_i^A, q_i)}, \tag{21}$$

where $\hat{b}_{12} = (n_1^R p_1^A - n_2^R p_2^A)/(Q_1 - Q_2)$ is the valuation of the marginal author (among those whose quality exceeds the high-quality journal's standard) who is indifferent between submitting to journal 1 or 2 and where $\hat{b}_j = n_j^R p_j^A / Q_j$ is the valuation of the marginal author (among those whose quality exceeds journal j's standard) who is indifferent between submitting to journal j and not submitting to any journal. The expression for the higher-quality journal's reputation in equation (20) is similar to the monopoly's in (19). The lower limit of integration on the second integral, $\max(\hat{b}_1, \hat{b}_{12})$, ensures that the author's valuation for certification b_i^A is high enough that, first, he prefers to submit to journal 1 than not submit at all and, second, prefers to submit to the higher- than the lower-quality journal conditional on submitting. The expression for the lower-quality journal's reputation has two terms in the numerator and denominator, reflecting two sources of demand. Journal 2 competes with journal 1 for the authors for whom $q_i \geq \hat{q}_1$ but for whom b_i^A is sufficiently low that they are not willing to pay the premium for the higher-reputation journal. Journal 2 has an effective monopoly over authors whose articles meet its but not journal 1's standards.

In view of the complicated expressions for journal quality and the odd implication that journal 2 may have more market power than 1 because 2 lacks a competitor with a lower quality threshold, an artifact of the restriction to two journals, we will focus most of our analysis on the free-entry equilibrium. Recall that the free-entry model from Section 6 involved a potentially unlimited number of journals $j = 1, \ldots, J$, and the accompanying equilibrium concept involved a set of prices for each journal such that neither active nor inactive journals could benefit from changing their prices.

Many of the insights from the free-entry equilibrium without quality certification in Section 6 carrry over to the case of quality certification. On the one hand, competition for authors drives the equilibrium toward niche articles that serve the interests of individual author types. On the other hand, economies of scale in bundling articles together that arise when $c^R > 0$ tend to lead to less refined partitions of author types. Without quality certification, Proposition 3 showed that the second effect leads to bundling of all articles together in a single journal. In the present model with quality certification, an offsetting effect is that authors of high quality articles with high benefits of certification (i.e., both high q_i and high b_i^A) would prefer not to be bundled together with all other authors in an average-quality journal. They would pay a premium to be distinguished in a high-quality journal. This effect leads to more refined partitions of authors into journals than without quality certification. In the limit as the distribution of q_i approaches a single value, the free-entry equilibrium converges to the one found in Proposition 3. In particular, if $c^R > 0$, the free-entry equilibrium involves a single journal serving all authors with free submission. Taking the other extreme, in the limit as a the variance of q_i grows without bound, as long as q_i and b_i^A are not perfectly negatively correlated, the premium that a segment of authors with both high q_i and high b_i^A would be willing to pay to distinguish themselves from the average author would grow without bound, and an entering journal would earn positive profit from serving them, even if the journal only carried a few readers on the other side. In this limit, the free-entry equilibrium cannot involve a single journal but would have to involve a partition of articles across several journals.

If $c^R = 0$, any economies of scale in bundling articles disappears, leaving only the force toward serving the interests of individual author types. Similar to case (ii) of Proposition 3, there is a continuum of journals in the free-entry equilibrium, each maximizing the net surplus of the targeted author type. The details of the equilibrium are slightly different than in Proposition 3. Given that authors care about quality certification rather than the number of readers, there can be free-entry equilibria in which journals earn positive profit. Authors may happen to sign up with journals that earn a profit from high reader fees that have low readerships. Entry by another journal with lower reader fees and a greater expected readership would not strictly tempt the author to jump to the entering journal given that the author is served in equilibrium by a journal with a quality standard perfectly matched to his own and at the lowest possible submission price. If, in addition to caring about certification, authors care slighly about number of readers, say having lexicographic preferences over quality certification first and readership second, then free-entry equilibria with positive journal profits would be eliminated, and only the one with low subscriber fees and zero profits would remain. Proposition 5 characterizes the full range of equilibria, zero profit and positive profit.

Proposition 5. *Assume $c^R = 0$. In all free-entry equilibria of the quality-certification model, there is a continuum of journals, with each quality q_i served by a different journal or journals. If the following inequality is satisfied for some*

p_j^R,

$$m^R[1 - F^R(p_j^R/q_i)](p_j^R - c) - c^A \geq 0, \tag{22}$$

then there exists a free-entry equilibrium in which a journal charges $p_j^{A*}(q_i) = 0$ *and* $p_j^{R*}(q_i)$ *equal to any* p_j^R *satisfying (22). Profit for journals of quality* q_i *is given by the left-hand side of (22) and may be positive. All authors of quality* q_i *submit regardless of* b_i^A*. If (22) is not satisfied for any* p_j^R*, then prices in the free-entry equilibrium satisfy*

$$p_j^{R*}(q_i) = \operatorname*{argmax}_{p_j^R \geq 0} \left\{[1 - F^R(p_j^R/q_i)](p_j^R - c)\right\} \tag{23}$$

$$p_j^{A*}(q_i) = c - p_j^{R*}(q_i) + \frac{c^A}{m^R[1 - F^R(p_j^{R*}(q_i)/q_i)]}. \tag{24}$$

Journals of quality q_i *earn zero profit. Authors of quality* q_i *and value for certification* $b_i^A \geq m^R[1 - F^R(p_j^{R*}(q_i)/q_i)][c - p_j^{R*}(q_i)] + c^A$ *submit their articles.*

8. Conclusion

The market for academic journals is important to study. Prices have risen to the point at which libraries are beginning to cancel significant titles (Weiss 2003), suggesting that subscriber demand is somewhat elastic, in turn suggesting the possibility for significant deadweight loss. The deadweight loss may be experienced on both sides of the journal market: readers because their access to significant scholarship is reduced and authors because their readership and thus their impact and citations are diminished. 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.

We analyzed equilibrium in a number of different market structures, ranging from monopoly to free entry. The monopoly case is relevant if it is thought that reputational capital or complex bundling strategies used by incumbents are sufficient entry barriers to afford the journal some market power. A monopoly journal would typically charge markups over marginal cost to both sides of the market, resulting in both significant submission fees and subscription fees, unless there is considerable asymmetry between the two sides. If, for example, the reader benefits dominate author benefits, either because there are many more readers than authors or because the given number of readers gain a high benefit per article read, then the monopolist will lower submission fees to attract more authors and extract more revenue from readers. In the extreme case, the monopolist will adopt a free submission policy. On the other hand, if author benefits dominate reader benefits, the monopolist will shade subscription fees down, adopting open access (free subscriptions) if the asymmetry is extreme.

The two models of competition we analyzed, duopoly and free entry, produce related results, although where they differ the most interesting results arguably come from the latter case. In the basic model in which articles are of homogeneous quality, free-entry equilibrium hinged on the value of the fixed cost of serving a reader, c^R. If $c^R = 0$, there are no economies of scale in journal operation. The stringent competition to sign up authors leads to the entry of a continuum of journals, each precisely targeting a different author type by offering a submission-fee/subscriber-base bundle that maximizes that type's surplus subject to a break-even constraint for the journal. This maximization does not necessarily result in a journal's offering free submission, because some author types may be willing to pay more for a journal with lower subscription fees and thus more readers. Indeed, journals targeting the authors with the highest benefit per reader b_i^A may offer open access and relatively high submission fees, as we saw in the example in Figure 1. If $c^R = 0$, there are economies of scale in journal operations in that bundling more articles together in fewer journals saves the duplication in the cost of serving readers c^R. The free-entry equilibrium in this case involves one operating journal serving all authors. This is of course an extreme result. In the extension to the case in which articles differ in quality and authors care about being certified by a journal that publishes articles of high average quality rather than the number of readers, a moderate number of journals can emerge in the free-entry equilibrium even with $c^R > 0$. The force toward consolidation provided by economies of scale is counteracted by a proliferating force: high-quality authors are willing to pay a premium to separate themselves from authors of lower-quality articles by publishing in a selective journal. As c^R falls, journals proliferate until at $c^R = 0$, a continuum of journals enters targeting each author type, where rather than being a scalar, author type is a vector including article quality as well as valuation of certification.

Non-profits are important players in the journal market, and we devoted a section to their analysis. Regardless of its idiosyncratic objectives—maximizing readership, maximizing the surplus of affiliated scholar members, etc.—a non-profit journal can exploit any market power it has or any other source of rent such as an external grant, advertising revenue, or cross subsidy from another activity to pursue its objectives. The more stringent the competition it faces, the less likely it can remain viable while pursuing its idiosyncratic objectives, although we derived conditions under which certain objectives can be reached even in a free-entry equilibrium in which the journal has no external subsidy.

We hope our model provides a framework that can be extended to further capture the complexity of the journals market and to treat new policy issues that arise as the market matures in the digital age. For example, future work could derive a dynamic extension of the model endogenizing incumbent journals' market power. In such an extension, an incumbent's market power could derive from its monopoly over the digital archive of its past issues or from lags in the adjustment of reputation. New policy issues that might be analyzed using the model include the welfare effects of allowing publishers to negotiate with libraries over large portfolios of journals, raising antitrust concerns relating to both bundling and price discrimination. Also, publishers have begun experimenting with complicated pricing schemes, including ones that offer the author the option to pay extra for open access. The welfare effects of such schemes, as well as the implications for equilibrium under various market-structure assumptions, could be studied using our framework.

Appendix A: Proofs of Propositions

Proof of Proposition 1: We will show $dp_j^A/dc^A \geq 0$ in equilibrium with a monopoly journal. The proof for $dp_j^R/dc^R \geq 0$ is analogous. Let Π^m denote the profit from equation (1) for a monopoly journal. Let subscripts denote partial derivatives, so that $\Pi_A^m \equiv \partial \Pi^m / \partial p_j^A$, $\Pi_{Ac^A}^m \equiv \partial^2 \Pi^m / \partial p_j^A \partial c^A$, $\Pi_{AR}^m \equiv \partial^2 \Pi^m / \partial p_j^A \partial p_j^R$, etc. Assume the following second-order conditions sufficient for a maximum hold: $\Pi_{AA}^m \Pi_{RR}^m > (\Pi_{AR}^m)^2$, $\Pi_{AA}^m < 0$, and $\Pi_{RR}^m < 0$. Then

$$\frac{dp_j^A}{dc^A} = \frac{\Pi_{Rc^A}^m \Pi_{AR}^m - \Pi_{Ac^A}^m \Pi_{RR}^m}{\Pi_{AA}^m \Pi_{RR}^m - (\Pi_{AR}^m)^2} \tag{A1}$$

$$\propto \Pi_{Ac^A}^m \tag{A2}$$

$$= -\frac{dn_j^A}{dp_j^A}, \tag{A3}$$

where $\propto$ means "has the same sign as". Equation (A1) holds by the implicit-function rule, (A2) holds since $\Pi_{AA}^m \Pi_{RR}^m > (\Pi_{AR}^m)^2$ and $\Pi_{RR}^m < 0$ by the second-order conditions and since $\Pi_{Rc^A}^m = 0$, and (A3) holds by differentiating (7) with respect to c^A. Equation (A3) is positive since $dn_j^A/dp_j^A = -m^A dF^A/dp_j^A < 0$. The constraint that prices must be non-negative means that the condition $dp_j^A/dc^A \geq 0$ must be stated as a weak rather than strict inequality.

We will show the sign of dp_j^A/dm^A is ambiguous using examples. Suppose b_i^A is uniformly distributed on $[0, \bar{b}^A]$ and b_k^R is uniformly distributed on $[0, \bar{b}^R]$. Then, if the second-order conditions from the previous paragraph hold, the implicit-function rule and brute-force calculations show

$$\frac{dp_j^A}{dm^A} \propto m^R \Big[p_j^A(\bar{b}^A + 3c - 2p_j^A - 2p_j^R - \bar{b}^R) + p_j^R(2\bar{b}^R + 2c - 2p_j^R) + \bar{b}^R(\bar{b}^A - \bar{b}^R) - c(\bar{b}^A + c) \Big] + 2c^A \bar{b}^R. \tag{A4}$$

In the limit as $m^R \to 0$, (A4) approaches $2c^A \bar{b}^R > 0$. Setting $c^A = c = 0$, in the limit as $\bar{b}^A \to 0$ and $\bar{b}^R \to \infty$, (A4) approaches $-m^R[(p_j^R)^2 + (\bar{b}^R - p_j^R)^2] < 0$. So (A4) can have either sign. □

Proof of Proposition 2: Consider an outcome with equal prices $p_j^A = p^A$ and $p_j^R = p^R$ for $j = 1, 2$. Note reader demand is equal across journals $n_j^R = n^R = m^R[1 - F^R(p^R)]$ for $j = 1, 2$ (unless $n_j^A = 0$ for some j, in which case $n_j^R = 0$).

Let Π_j be journal j's profit in this outcome. Any outcome with $\Pi_j < 0$ cannot be an equilibrium because j can guarantee itself zero profit by setting sufficiently high prices that it gets no author or reader demand. We can also rule out $\Pi > 0$ in equilibrium. Without loss of generality, suppose $\Pi_1 > 0$ and $\Pi_1 \geq \Pi_2$. After rearranging equation (1), Π_j can be written

$$\Pi_j = n_j^A[n^R(p^A + p^R - c) - c^A] - c^R n^R. \tag{A5}$$

Since $\Pi_j > 0$ and $c^R n^R \geq 0$, the term in square brackets in (A5) is positive. For $\Pi_1 > 0$ in (A5), $n_1^A > 0$. At least one of the prices p^A, p^R is positive or else $\Pi_j \leq 0$. Journal 2 can undercut this positive price slightly, reducing the positive term in square brackets in (A5) by an arbitrarily small amount but increasing author demand by a discrete amount from n_2^A to at least $n_1^A + n_2^A$, a strictly profitable deviation. This establishes that $\Pi_j = 0$ in any symmetric, pure-strategy equilibrium.

We next turn to the three cases, supposing throughout that $\Pi_j = 0$.

Case (i): $c^R > 0$. Consider an outcome with symmetric prices p^A, p^R such that $p^A > 0$ and $\Pi_j = 0$, $j = 1, 2$. Also suppose $n_j^A, n^R > 0$ for some $j = 1, 2$, so the outcome is nontrivial. We will show that this outcome cannot be an equilibrium. Before proceeding, we will establish two facts that will be used later in the proof of this case. First, $\Pi_j = 0$ and $n_j^A, n_j^R > 0$ for some j implies $n_j^R(p^A + p^R - c) = c^A + c^R n_j^R / n_j^A$, in turn implying

$$n_j^R(p^A + p^R - c) > c^A. \tag{A6}$$

for some j since $c^A, n_j^A, n_j^R > 0$ for some j. Second, $n_j^A > 0$ for some j implies

$$n_j^A \leq n_1^A + n_2^A \quad \text{for some } j = 1, 2. \tag{A7}$$

Suppose a journal j for which $n_J^A < n_1^A = n_2^A$ deviates to $\tilde{p}_j^A < p^A$, holding p^R and n_j^R fixed. Letting $\tilde{n}_j^A$ be author demand and $\tilde{\Pi}_j$ be profit resulting from the deviation, for $\tilde{p}_j^A$ sufficiently close to p^A,

$$\begin{aligned} \tilde{\Pi}_j &= \tilde{n}_j^A[n_j^R(\tilde{p}_j^A + p^R - c) - c^A] - c^R n_j^R && \text{(A8)} \\ &\geq (n_1^A + n_2^A)[n_j^R(\tilde{p}_j^A + p^R - c) - c^A] - c^R n_j^R && \text{(A9)} \\ &> n_j^A[n_j^R(p^A + p^R - c) - c^A] - c^R n_j^R. && \text{(A10)} \end{aligned}$$

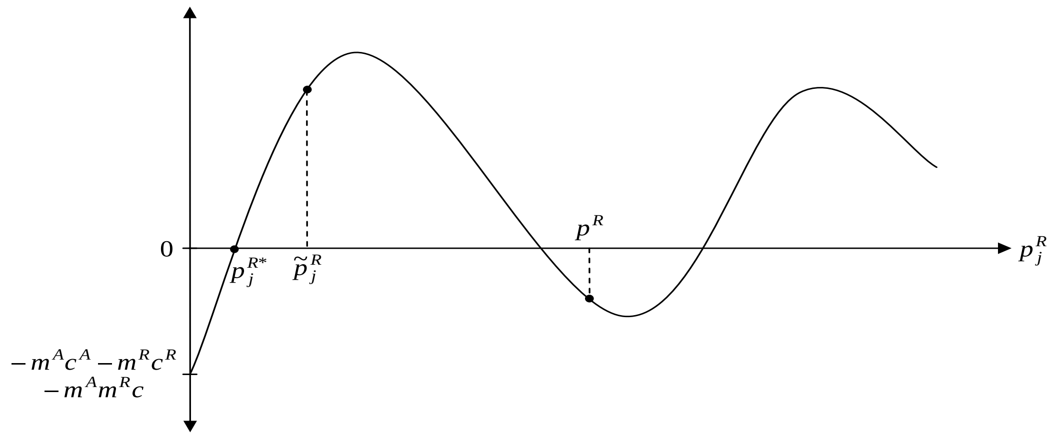

Figure 2: Schematic diagram of zero-profit equation (14).

Equation (A8) holds by definition. Condition (A9) holds because journal j induces all submitting authors to submit to it by slightly undercutting p^A, so submissions increase to more than $n_1^A + n_2^A$. Furthermore, as $\tilde{p}_j^A \to p^A$, $n_j^R(\tilde{p}_j^A + p^R - c) \to n_j^R(p^A + p^R - c) > c^A$ by (A6), implying the bracketed factor in (A8) and (A9) is positive for $\tilde{p}_j^A$ sufficiently close to p^A. Condition (A10) holds for $\tilde{p}_j^A$ sufficiently close to p^A by (A7). But (A10) equals Π_j, implying $\tilde{\Pi}_j > \Pi_j$. Therefore, $p^A = 0$ in a nontrivial, symmetric, pure-strategy equilibrium.

The analysis of this case concludes by showing p_j^{R*} must be the lowest implicit solution to (14) if such a solution exists. Figure 2 provdes a schematic diagram of equation (14). The crucial feature of the solid curve is that it is positively sloped where it first cuts the horizontal axis because it starts off below the axis for $p_j^A = 0$, as shown. Hence, for any $p^R > p_j^{R*}$, journal j can deviate to some price $\tilde{p}_j^R$ below p^R and above p_j^{R*}, increasing the number of readers and thus stealing all authors from the competing journal. Journal j's deviating profit is thus given by the solid curve in Figure 2, which is positive for a region of prices $\tilde{p}_j^R$ slightly greater than p_j^{R*}.

Case (ii): $c^R = 0$, $\max(c^A, c) > 0$. Consider a symmetric equilibrium involving open access (i.e., $p^R = 0$). Then $n^R = m^R$, and

$$\frac{m^A}{2}[1 - F^A(p^A)][m^R(p^A - c) - c^A]. \tag{A11}$$

Since $\Pi = 0$ for this to be an equilibrium, p^A solves the equation setting (A11) equal to 0; indeed, by arguments associated with Figure 2, p^A is the lowest such solution. Thus, $p^A = \min(\bar{b}^A, c + c^A/m^R)$. If $\bar{b}^A \leq c + c^A/m^R$, then $n^A = 0$, and there is no nontrivial open-access equilibrium. So suppose

$$\bar{b}^A > c + \frac{c^A}{m^R}, \tag{A12}$$

implying $p^A = c + c^A/m^R$. We will determine the condition under which a journal j has no profitable deviation to some $\tilde{p}_j^A$ and $\tilde{p}_j^R$.

The only relevant deviation to consider is $\tilde{p}_j^A = p^A - \epsilon_j^A$ for some $\epsilon_j^A \in (0, c + c^A/m^R)$ and $\tilde{p}_j^R = \epsilon_j^R$ for some $\epsilon_j^R \in (0, \bar{b}^R)$. Deviations with $\tilde{p}_j^R < p^R = 0$ can be ruled out by the non-negative price constraint. Deviations with $\tilde{p}_j^R = 0$ and $\tilde{p}_j^A < p^A$ can be ruled out because deviation profits can be shown to be negative. Deviations with $\tilde{p}_j^R = 0$ and $\tilde{p}_j^A > p^A$ can be ruled out because the deviating journal loses all submissions, and deviation profit is thus 0.

Upon substituting and rearranging, deviation profit, $\tilde{\Pi}$, can be shown to equal

$$\tilde{n}_j^A \left\{ m^R[1 - F^R(\epsilon_j^R)](\epsilon_j^R - \epsilon_j^A) - F^R(\epsilon_j^R)c^A \right\}. \tag{A13}$$

Now $\tilde{n}_j^A > 0$ if and only if, for some b_i^A,

$$\tilde{n}_j^R(b_i^A - \tilde{p}_j^A) > \max\left[0, m^R\left(b_i^A - c - \frac{c^A}{m^R}\right)\right]; \tag{A14}$$

i.e., there exists an author i who derives more surplus from submitting to the deviating journal than either not submitting or submitting to the nondeviating journal. Given we have constrained ϵ_j^R to satisfy $\epsilon_j^R < \bar{b}^R$, implying $\tilde{n}_j^R > 0$, condition (A14) is satisfied for some b_i^A, in particular $b_i^A = c + c^A/m^R$. Therefore, by (A13), $\tilde{\Pi} > 0$ if and only if there exists $\epsilon_j^A \in (0, c + c^A/m^R)$ and $\epsilon_j^R \in (0, \bar{b}^R)$ such that

$$m^R[1 - F^R(\epsilon_j^R)](\epsilon_j^R - \epsilon_j^A) > F^R(\epsilon_j^R)c^A. \tag{A15}$$

If (A15) holds strictly for some $\epsilon_j^R \in (0, \bar{b}^R)$ after having set $\epsilon_j^A = 0$, then by continuity (A15) will also hold for some $\epsilon_j^A > 0$ for some $\epsilon_j^R \in (0, \bar{b}^R)$. We can thus eliminate ϵ_j^A in (A15) and see that $\tilde{\Pi} > 0$ if and only if there exists $\epsilon_j^R \in (0, \bar{b}^R)$ such that $m^R[1 - F^R(\epsilon_j^R)]\epsilon_j^R > F^R(\epsilon_j^R)c^A$, or equivalently if

$$\max_{\epsilon_j^R \in (0,\bar{b}^R)} K(\epsilon_j^R) > \frac{c^A}{m^R}, \tag{A16}$$

where $K(\cdot)$ is defined in equation (16). Together, conditions (A12) and (A16) yield condition (15) in the statement of the proposition. □

Case (iii): $c^A = c^R = c = 0$. If costs are zero, the only prices consistent with zero profit and the non-negativity constraints on prices are $p^A = p^R = 0$. □

Proof of Proposition 3: The proof that journals' profits are zero in the free-entry equilibrium is analogous to the proof that duopoly journals' profits are zero in Proposition 2. We turn to analyzing the three listed cases.

Case (i): $c^R > 0$. The equilibrium outcome and proof are identical to that in case (i) of Proposition 2.

Case (ii): $c^R = 0$, $\max(c^A, c) > 0$. Consider an outcome in which a positive measure of authors M are served by a journal j that does not maximize the authors' surpluses

$$n_j^R(b_i^A - p_j^A) = m^R[1 - F^R(p_j^R)](b_i^A - p_j^A) \tag{A17}$$

subject to the non-negative price constraints $p_j^A, p_j^R \geq 0$ and the break-even constraint $n_j^A[n_j^R(p_j^A + p_j^R - c) - c^A] - c^R n_j^R \geq 0$, or equivalently

$$m^R[1 - F^R(p_j^R)](p_j^A + p_j^R - c) - c^A \geq 0. \tag{A18}$$

Then there exists $\tilde{p}_j^A, \tilde{p}_j^R > 0$ such that

$$m^R[1 - F^R(\tilde{p}_j^R)](b_i^A - \tilde{p}_j^A) > m^R[1 - F^R(p_j^R)](b_i^A - p_j^A) \tag{A19}$$

and

$$m^R[1 - F^R(\tilde{p}_j^R)](\tilde{p}_j^A + \tilde{p}_j^R - c) - c^A > 0. \tag{A20}$$

By continuity, for small enough $\epsilon > 0$, conditions (A19) and (A20) also hold for all author types in an ϵ neighborhood $N_\epsilon(b_i^A) = (b_i^A - \epsilon, b_i^A + \epsilon)$ around b_i^A within measure M. A journal can enter the market, charge prices $\tilde{p}_j^A$ and $\tilde{p}_j^R$, and make positive profit equal to the positive marginal profit per author in condition (A20) times the measure of authors these prices attract, at least the measure of $N_\epsilon(b_i^A)$.

To show that expression (17) is equivalent to maximizing author type b_i^A's gross surplus subject to constraint (A18) and non-negative price constraints, note that (A18) binds at an optimum since lowering either price increases the author's surplus, but (A18) is violated if prices are set to zero. Treating (A18) as an equality and solving for p_j^A,

$$p_j^A = \frac{c^A}{m^R[1 - F^R(p_j^R)]} + c - p_j^R. \tag{A21}$$

Substituting equation (A21) into (A17) gives the objective function in (17). Constraining $p_j^A \geq 0$ in (A21) gives the constraint on p_j^R in (17).

Case (iii): $c^A = c^R = c = 0$. The equilibrium outcome and proof are identical to that in case (i) of Proposition 2. □

Proof of Proposition 4: Suppose $c^R > 0$ and equation (14) has an implicit solution for p_j^R. Proposition 2 implies that, if it exists, a closed-access equilibrium is such that $p_j^{A*} = 0$ and p_j^{R*} is the implicit solution to (14). The only remaining possibility to consider when costs are endogenous is that there might be a profitable deviation to an open-access outcome $\tilde{p}_j^A$ and $\tilde{p}_j^R = 0$. We will derive the condition under which such a deviation is strictly profitable. Deviation profit equals

$$\tilde{\Pi} = \tilde{n}_j^A[m^R(\tilde{p}_j^A - c) - c^A] \tag{A22}$$

since all readers subscribe to the open-access deviator and its fixed reader costs are zero. Equation (A22) can be made positive if and only if $\tilde{n}_j^A > 0$ at the value of $\tilde{p}_j^A$ for which the bracketed factor equals 0, that is, for $\tilde{p}_j^A = c + c^A/m^R$. To see this, note that if n_j^A can be made strictly greater than 0 for the $\tilde{p}_j^A$ for which the bracketed expression were exactly 0, $\tilde{p}_j^A$ could be increased slightly to make the bracketed term strictly positive and still have $\tilde{n}_j^A > 0$, so that $\tilde{\Pi} > 0$. To compute $\tilde{n}_j^A$, note that an author would submit to the deviating journal if and only if his surplus $m^R(b_i^A - \tilde{p}_j^A)$ exceeds the surplus $n^{R*}b_i^A$ from submitting to the closed-access journal (since this surplus is always positive, we can ignore the option of not submitting to any journal), implying $b_i^A > m^R\tilde{p}_j^A/(m^R - n^{R*})$, in turn implying $\tilde{n}_j^A = 1 - F^A(m^R\tilde{p}_j^A/(m^R - n^{R*}))$. To ensure $\tilde{n}_j^A > 0$, $m^R\tilde{p}_j^A/(m^R - n^{R*}) < \bar{b}^A$. Substituting $\tilde{p}_j^A = c + c^A/m^R$ and $n^{R*} = 1 - F^R(p_j^{R*})$ and rearranging gives condition (18). □

Proof of Proposition 5: Arguments along the lines of the proof of case (ii) of Proposition 3 can be used to show that the free-entry equilibrium maximizes $b_i^A q_i - n_j^R p_j^A$, the net surplus of author type (b_i^A, q_i) (now a vector type rather than a scalar) subject to non-negative price constraints $p_j^A, p_j^R \geq 0$ and a break-even constraint for the journal $n_j^A[n_j^R(p_j^A + p_j^R - c) - c^A] \geq 0$. Noting that $b_i^A q_i$ is an inessential constant in the objective function and making the change of variables $\tilde{p}_j^A = n_j^R p_j^A$, the maximization problem can be rewritten $\min \tilde{p}_j^A$ subject to $\tilde{p}_j^A \geq 0$, $p_j^R \geq 0$, and

$$\tilde{p}_j^A \geq c^A - m^R[1 - F^R(p_j^R/q_i)](p_j^R - c). \tag{A23}$$

The solution depends on which constraint, $\tilde{p}_j^A \geq 0$ or (A23), binds first, which in turn depends on the sign of

$$\max_{p_j^R \geq 0} \left\{ c^A - m^R[1 - F^R(p_j^R/q_i)](p_j^R - c) \right\}, \tag{A24}$$

where (A24) is the maximized value of the right-hand side of constraint (A23). If (22) holds, then (A24) is non-positive, and constraint $\tilde{p}_j^A \geq 0$ binds before (A23). Free-entry equilibrium thus involves $p_j^{A*} = 0$ and any p_j^R that satisfies (A23) with 0 substituted in the left-hand side. If (22) does not hold, then p_j^{A*} can be found by treating (A23) as an equality with p_j^R set to maximize the right-hand side. Dividing $\tilde{p}_j^{A*}$ through by $m^R[1 - F^R(p^{R*}(q_i)/q_i)]$ gives the value of p_j^{A*} in the statement of the proposition. □

Appendix B: Empirical Evidence on Assumptions

This appendix provides empirical evidence supporting the assumption of that journals adjust their prices in the transition to long-run equilibrium, so that author prices will vary with the number of readers and reader prices will vary with the number of articles from year to year. As Propositions 2 and 3 showed, in the print-journal world with $c^R > 0$, which is the relevant case for most of the history of the academic journal market, equilibrium involves free submission for authors. Over the last twenty years, most business and economics journals charged low or no submission fees with little year-to-year variation, as predicted. The empirical analysis will thus focus on the subscription side, verifying that subscription fees vary with the number of articles from year to year.

Table 1 provides descriptive statistics for the panel data used to analyze subscription fees. Our data set includes all major business and economics journals (all 227 listed on ISI in 1998) over the period 1988–2000. The table breaks the data down by for-profit and non-profit journals. Most subscription revenue comes from libraries, so we focus on library subscription fees in our analysis. For-profit journals had higher subscription fees on average than non-profits (381 compared to 90), had more articles per journal-year, but had fewer citations in a year to past volumes, suggesting that non-profits were on average cheaper but higher quality, echoing Bergstrom's (2001) findings.

Table 2 provides regression results for library subscription fees. The regressions include fixed journal and time effects. The coefficient on $\ln(\textit{ARTICLES}_{jt})$ is positive and statistically significant in all ordinary least squares regressions. One concern is that $\textit{ARTICLES}_{jt}$ may be endogenous. For example, a journal may seek to boost its reputation by accepting a lower percentage of articles, at the same taking advantage of increased reputation by increasing price, leading the coefficient on $\ln(\textit{ARTICLES}_{jt})$ to be biased downward. Indeed, running two-stage least squares with lagged values of the endogenous variables as instruments, the coefficient on $\ln(\textit{ARTICLES}_{jt})$ increases for for-profit journals and remains statistically significant but falls for non-profit journals, becoming negative and statistically insignificant. The results suggest that for-profit journals adjust their prices from year to year depending on the number of articles published. Non-profit journals behave differently; their prices may be low enough that they do not need to be adjusted to retain library subscriptions as the number of articles varies. The regressions account for quality by including $\ln(\textit{CITATIONS}_{jt})$. This has little effect on the estimates for $\ln(\textit{ARTICLES}_{jt})$ but is itself positive and generally statistically significant, consistent with Dewatripont *et al.* (2006).

Table 1: Descriptive Statistics for Panel of Business and Economics Journals

	For-profit journals				Non-profit journals			
	Mean	Std. Dev.	Min.	Max	Mean	Std. Dev.	Min.	Max
$LIBFEE_{jt}$	381	431	27	5,729	90	64	9	455
$ARTICLES_{jt}$	54	91	3	1,504	42	29	5	224
$CITATIONS_{jt}$	243	288	1	2,182	409	519	1	3,473

Data and sources: Unbalanced panel over the years 1988–2000 of 145 for-profit journals, accounting for 1,521 journal-year observations, and 82 non-profit journals, accounting for 947 journal-year observations. $LIBFEE_{jt}$ is the library subscription fee for journal j in year t in nominal terms. $ARTICLES_{jt}$ is the number of articles published by journal j in year t. $CITATIONS_{jt}$ is the number of citations in ISI-listed journals published in year t to articles published by journal j in from year $t-4$ to t (five years total). $LIBFEE_{jt}$ collected by the authors from individual journals and other sources. $ARTICLES_{jt}$ and $CITATIONS_{jt}$ from ISI Journal Performance Indicators Database.

Table 2: Regression Results for Library Subscription Fees Using a Panel of Business and Economics Journals

	For-profit journals			Non-profit journals		
	OLS	OLS	2SLS	OLS	OLS	2SLS
$\ln(ARTICLES_{jt})$	0.143^{**} (0.015)	0.131^{**} (0.015)	0.348^{**} (0.131)	0.046^{*} (0.018)	0.036^{*} (0.018)	-0.423 (0.472)
$\ln(CITATIONS_{jt})$	—	0.039^{**} (0.007)	0.058^{*} (0.023)	—	0.043^{**} (0.011)	0.055 (0.035)
R^2	0.964	0.965	—	0.930	0.931	—
J	145	145	145	82	82	82
$J \times T$	1,521	1,521	1,216	947	947	776

Notes: See Table 1 for variable definitions and data sources. Dependent variable is $\ln(LIBFEE_{jt})$. OLS denotes ordinary least squares regressions; 2SLS denotes two-stage least squares regressions in which the additional instruments are $ARTICLES_{jt-1}$, $ARTICLES_{jt-2}$, $CITATIONS_{jt-1}$, and $CITATIONS_{jt-2}$. Regressions include a full set of fixed journal and year effects. The set of fixed journal effects are jointly significantly different from zero at the one percent level in all regressions, and similarly for the set of fixed year effects. J is the number of journals and $J \times T$ the number of observations in the regression. Standard errors in parentheses below coefficient estimates. Significantly different from zero in a two-tailed test at the *five-percent level, **one-percent level.

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