A Portfolio Model of Journal Pricing : Print v. Digital

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This paper offers a model of journal pricing that incorporates the portfolio demand behavior of libraries. The model is used to analyze four market regimes that differ with respect to the ability or inability of publishers to (1) price discriminate among customers and (2) bundle their journals. One of these regimes – no bundling or price discrimination – corresponds to the print environment that has been observed in recent decades. Another regime – bundling and price discrimination – best describes the emerging digital environment. The model and associated numerical simulations demonstrate that a sharp decline in marginal costs can explain the current shift between regimes.

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Libraries act as intermediaries between information consumers and publishers. They offer diverse communities of users access to a multitude of monographs and journals. By aggregating the overlapping demands of numerous users, substantial efficiencies can be achieved in a print environment, including copy sharing and reduced transaction costs (such as those associated with ordering, payment and storage). Even in the emerging world of digital distribution the role of libraries in achieving efficiencies and reducing transaction costs seems secure.

The user benefits arising from this intermediary role are fairly clear. What is perhaps less obvious is the potential impact of this role on publisher behavior. In particular, the fact that libraries, given their acquisition budgets, attempt to assemble broadly-defined collections suggests that their substitution possibilities among various products may be constrained. Rather than choosing, for example, one of several economics journals, most research libraries will purchase as many as possible (since from a user's perspective articles in one title are, at best, very imperfect substitutes for those appearing in other journals). The objective of this paper is to model journal pricing behavior in this demand environment and to consider how the transition from print to digital distribution may influence seller conduct.

The scholarly journals market has received modest attention in the economics literature. Ordover and Willig (1978), Phillips and Phillips (2002), and Issman-Weit and Shy (2003) model the pricing of a single print journal to institutional and individual subscribers. Chuang and Sirbu (1999) also consider the case of a single journal but in a digital environment. Given the lower transaction costs associated with this new environment, they demonstrate that mixed bundling (sales of individual articles as well as the "bundled" journal) can be a profit-maximizing strategy. Fay and Mackie-Mason (1999) extend Chuang and Sirbu's demand framework to allow for

competition between bundles of information goods.[1] They compare the profitability and welfare properties of bundling in the monopoly and duopoly cases. In both of these papers, the analytical difficulties posed by the "N-good" bundling problem lead to simplifying assumptions, e.g. firms sell either one bundle containing all N goods and/or each of the individual goods, there is no price discrimination (and bundle components share a common price if sold separately), and the use of numerical methods is necessary to generate results. Finally, Bergstrom (2001) discusses how the demand aggregation facilitated by libraries increases the profitability of an individual title and reduces user surplus.[2] In contrast, this paper offers a model of journal pricing that incorporates the behavior of libraries in a market populated by multiple titles (each of which is a bundle of articles) and firms. Libraries attempt to maximize the quality or use value of their journal collections, subject to a budget constraint and observed prices. The result is a demand for a *portfolio* of many titles. In the print environment, for example, this means that titles are ranked in terms of their cost/use ratio and then purchased if they "fit" into a library's budget. In other words, unlike most markets involving differentiated products, it is not appropriate to model demand as a discrete choice process. Rather, the typical library attempts to provide access to as many journals as possible through a combination of subscriptions and inter-library exchanges.

Given this portfolio demand, I consider four different distribution regimes. In each case, a regime is defined by the ability or inability of publishers to (1) price discriminate among

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[1] Both Chuang and Sirbu (CS) and Fay and Mackie-Mason (FMM) model *final* consumer demand for an N-good bundle(s) of articles or information goods. They assume that users rank each article in decreasing order of preference, and in the case of FMM, that articles sold by different firms are imperfect substitutes. Then given prices, consumers maximize their surplus. In this paper I specifically model the demand behavior of *libraries*. Although the CS and FMM framework is similar in one respect – libraries do rank *journals* according to cost/use ratios – my approach incorporates an additional element: the library budget constraint.

[2] The remaining papers are empirical in scope, including Lieberman, et. al. (1992), Chressanthis and Chressanthis (1994), and McCabe (2002).

customers and (2) bundle their journals.[3] One of these regimes – no bundling or price discrimination – corresponds to the print environment that has been observed in recent decades. In the print environment, journals are typically unbundled, price discrimination among libraries is not observed and entry by new titles is fairly common. Another regime – bundling and price discrimination – best describes the digital environment that is expected to replace the print regime in the very near future.[4] In this environment, publishers are able to charge library-specific prices and thus approximate first-degree price discrimination for two reasons: (1) they have precise information about each library's journal expenditures and digital use patterns, and (2) arbitrage opportunities are greatly reduced in the digital environment (access to a particular library's bundle can be and is restricted to specific IP addresses). Note also that the major commercial bundles consist of hundreds of titles, e.g., Elsevier's Science Direct product includes more than 1700 titles. Although entry at this scale remains possible, its likelihood would appear to be low. Relative to the stock of existing titles, the annual rate of entry (and exit) at the individual title level is minuscule even for major publishers.

In this context, two pricing models are proposed. The first permits analysis of the two distribution regimes in which no price discrimination is allowed. In this two-period model, I

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[3] Mixed bundling is not considered here for two reasons. First, because I assume that libraries' valuations for journals are positively correlated, the standard motivation for mixed bundling – negative correlation in consumer valuations – is absent. Second, the ability to price discriminate in this paper satisfies the same objective as mixed bundling does in Chuang and Sirbu (1999), and Fay and Mackie-Mason (1999). That is, in both of those papers, mixed bundling permits firms to set different prices for high and low demand buyers. Here, price discrimination allows publishers to set prices based on library budgets.

[4] Beginning in 1998 some publishers began distributing their journals in both print and digital format. Currently, this practice is ubiquitous among publishers and most libraries have opted to purchase both formats for most of their journals. In the digital case, bundling and price discrimination is the general rule. Evolution of the market towards a digital-only future continues. Publishers now offer a small discount if a library drops its print subscriptions and libraries have begun to exploit this opportunity. Once the uncertainty about responsibility for digital archiving has been resolved it is expected that this transition will occur quickly.

assume the existence of two types of libraries that differ according to the size of their budgets ("small" and "large"). In the second period, the pricing strategies for a particular journal is determined by the distribution of these budgets, the nature of the distribution regime, the journal's use value and the values of competing titles (with the impact of the latter depending on the ownership structure). In the first period, owners choose whether to sell to all libraries or just large budget libraries. The second model can be applied to the remaining two cases, where price discrimination is permitted. Since all titles compete for sales to each of the two library types, the first period of the model described above is eliminated. In both models, prices are increasing in a journal's own use value and decreasing in the aggregate use value of the competing titles.[5] In each of these regimes, mergers between competing firms can be profitable (this result depends on the structure of ownership).[6] As in more conventional markets, this result is due to the internalization of pecuniary externalities.

Furthermore, the analysis indicates that, depending on the relative size of marginal costs, a single distribution regime will tend to dominate the others (in terms of firm profitability). The print distribution regime (no bundling or price discrimination) is usually preferred by incumbent firms when marginal costs are relatively high. In contrast, the digital regime (bundling and price discrimination) is preferred when marginal costs approach zero.[7] The

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[5] McCabe (2000) offers evidence that journal prices are increasing in use value, as proxied by citation counts.

[6] McCabe(2002) provides evidence that recent journal mergers resulted in price increases.

[7] Bakos and Brynjolfsson (1999) show that, in a single price environment, that the bundling of information goods, i.e. products with zero or very low marginal costs, is profit maximizing when valuations for the component products are randomly distributed. However, when correlations exist between component valuations and other factors, the value of the bundle does not converge for the average buyer. If so, bundling creates excessive deadweight losses. In this paper we assume that libraries agree on the relative ranking of journal valuations and that the valuations themselves are positively related to the size of a library's user community. Under these conditions, the Bakos and Brynjolfsson bundling result does not hold.

intuition for this marginal cost sensitivity is that selling the same bundle to all libraries, including those that would select only a (small) subset of the available titles from the bundle under the print regime is too costly when marginal costs are large enough. Conversely, when marginal distribution costs approach zero (in a digital environment) the strategic advantages associated with bundling, e.g. foreclosure of less valuable bundles, more than offset any cost inefficiencies. Furthermore, although greater foreclosure may or may not lower the average quality of library journal collections, a decline in scientific diversity does occur. That is, the quantity of available published materials is reduced.

The paper is organized as follows. I first review the nature of journal demand. Two pricing models are then presented. The first permits analysis of the two distribution regimes in which no price discrimination is allowed. The second model can be applied to the remaining two cases, where price discrimination is permitted. Using these models, a numerical example is constructed in which each of the regimes are evaluated at two different levels of marginal costs and the dominant regimes are identified. I conclude with a brief discussion of the results as well as suggestions for future research.

1. Journal Demand

In scholarly publishing, experience as a user suggests that each *unique* journal title constitutes a distinct market. For example, no one would argue that articles in *Brain Research* could be easily substituted for ones in the *New England Journal of Medicine*, much less those in the *International Journal of Industrial Organization*.[8] This prior about market definition implies

[8] If each title corresponds to a distinct market, then owners of individual titles already have the capacity to achieve monopoly returns; a corollary is that mergers don't matter.

that demands for individual titles are unrelated. However, this intuition proved to be incorrect, at least for the major purchasers of science, technology and medical (STM) journals, the libraries. Discussions with dozens of librarians revealed the following: purchase of print academic journals by libraries is generally based on two factors — annual subscription price and expected usage. To assemble and maintain their collections, most libraries appear to construct a cost per use ratio for each title.[9] Given a budget for a relevant academic field, e.g., biomedicine, they then proceed to rank journals from lowest to highest in that field according to this ratio, and identify a cutoff above which titles need to be canceled; conversely, if their holdings in the relevant field do not exhaust the budget, additional titles can be purchased until the budget constraint is met. From year to year, as budgets and titles' usage change, collections are adjusted accordingly.[10] Over the past decade or so the general trend is for increases in library budgets to lag journal price inflation; a consequence is that many libraries have been forced to re-allocate dollars from monographs to journals, to postpone the purchase of new journal titles, and in some cases, to cancel titles.

The most interesting aspect of library journal acquisition, of course, is that individual titles within a given field are considered simultaneously. So, for example, bio-medical libraries group titles from various sub-fields, e.g. neurology, biochemistry, clinical medicine, etc., into a single "portfolio" and broadly apply the cost per use criterion. Thus, titles compete with each other for budget dollars across an entire field, rather than across a narrow sub-field, as intuition

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[9] This claim is literally true for medical libraries; though other types of academic libraries may not be as precise in their processes, they appear to behave in similar fashion.

[10] This type of constrained optimization problem is commonly referred to in the operations research literature as a "knapsack" problem. Note that in practice a library's budget constraint may be "soft"; it may be expanded slightly to accommodate the marginal journal that doesn't quite "fit" the budget. For an introduction to this issue in the OR literature see "Introduction to Operations Research Techniques" by H. Daellenbach and J. George, Allyn and Bacon (1978).

might otherwise suggest (an intuition based on the perspective of the typical user of journal materials). Furthermore, since journal content is highly differentiated even within sub-fields, libraries try to provide access to as many STM journals as possible through a combination of subscriptions and inter-library exchanges.

As library collections evolve from print to digital, much of the preceding discussion is likely to remain true, albeit with the individual journal replaced by journal bundles. Libraries will continue to rank various bundles on the basis of cost/use. I would expect that more libraries will behave like medical libraries currently do in the print environment. That is, since many types of libraries will have access to digital use data, procurement decisions will on average be based on better information, improving efficiency.

2. A Journal Pricing Model

Commercial journal publishers, like firms in any industry, will take into account the structure of demand and the likely strategies of competitors when setting prices. As described earlier, libraries – which constitute the bulk of demand for STM journals – attempt to purchase the most "use value" given their budgets for serials.[11] Depending on the distribution regime, this amounts to ranking journals or bundles of journals on a cost/use basis and identifying a threshold cost/use value above which titles are no longer added (the budget is exhausted).

More formally, suppose there exists T journal products that have different use values,

[11] To simplify the analysis, the possibility of inter-library exchanges is ruled out. This assumption implies that, on a cost/use basis, the cost of inter-library loans exceeds the costs of all subscriptions (Note that licenses for digital journal bundles often contain terms that satisfy this assumption.). Also, the model assumes that libraries make no duplicate purchases, an assumption that is generally correct except for the highest-use journals.

u_t.[12] Then given the price for each product, p_t, libraries can rank them on a cost/use basis,

$$p_{T-n}/u_{T-n} < p_{T-m}/u_{T-m} < .... \quad \text{where } 0 < m,n < T$$

And given some budget B, a library can choose products for its collection according to this ranking until B is fully allocated. The cost/use ratio for the last product added, p^*/u^* can be used to determine subsequent additions and cancellations of titles. Note that if it is not possible for a library to exhaust its acquisitions budget in this fashion (due to product lumpiness), I assume that they select the marginal product to maximize total use value, even if this violates the cost/use calculus.

To examine how prices are set in this demand environment I consider four distribution regimes that are defined by the ability or inability of publishers to (1) price discriminate among customers and (2) bundle their journals. For technical reasons that will soon be apparent it is easiest to discuss these four regimes two at a time: first, the two non-price discrimination cases, followed by the pair in which price discrimination is allowed. Within each pair, relative profitability and efficiency will be considered, and once this done, a comparison across pairs will be constructed.

No Price Discrimination

Case A: No Bundling (the "print environment")

Suppose that there are two types of library budgets, B_S and B_L, respectively, and $B_S < B_L$ (the analysis can be generalized to include additional budget classes). The corresponding population of each type is N_S and N_L (where $N_S + N_L > 2$). I assume that *T* titles are purchased

[12] To allow for the possibility that journal usage will differ from library to library I permit the u_t to vary across institutions. However, I assume that the ratio u_t / u_s is constant in all libraries for any pair of titles, t and s. This assumption guarantees that cost/use rankings are identical across libraries. Again, this assumption is generally validated by the author's current research assessing digital journal use.

by libraries, and that a potential entrant title exists whose usage value is less than that of any of the titles purchased by the libraries.[13] Each of these titles are sold by a separate publisher; one of these firms. This assumption is later relaxed to allow for the possibility of multi-journal firms. No price discrimination is allowed and thus annual subscriptions are sold at a single price. Journal *i*'s production costs consist of a fixed component, F > 0 (the so-called "first-copy" costs plus any other one-time costs such as advertising), and a constant marginal cost, $c \geq 0$ where $B_S > c$. All of this information, including each title's use value, is common knowledge.

Consider the following four period scenario. In the first period, given the anticipated strategies of its competitors, each of the T firms determine whether it is more profitable to sell to all libraries or just those with large budgets, and then reports its choice (as I will show, the potential entrant is indifferent between these two choices). In the second period, each firm announces its subscription price(s), including that for the potential entrant. Libraries then make purchase decisions and, finally, selected firms publish their journals. The "game" in this scenario involves the first two periods. Our analysis focuses on this two-period game.

I first consider the end-period pricing strategies. Suppose *z* (*T - z >0*) titles are purchased by all libraries. For sales to be made to the entire set of buyers by each of these journals it must be true that

$$p_1 + p_2 + p_3 + \ldots + p_z \leq B_S \qquad (1)$$

Similarly, for the remaining *T-z* titles sold only to the large budget libraries,

$$p_{z+1} + p_{z+2} + p_{z+3} + \ldots + p_T \leq B_L - B_S \qquad (2)$$

[13] If this latter claim was not true, then any equilibrium I identify consisting of the *T* titles would not exist. Given the libraries' objective, they would prefer to exchange one or more of the purchased journals for the entrant title.

With these budget constraints in mind, how do firms set prices? Consider the titles sold to all libraries. Suppose their prices are set so that the corresponding cost/use ratios are equal, that is,

$$\frac{p_1}{u_1} = \frac{p_2}{u_2} = \ldots = \frac{p_z}{u_z} \qquad (3).$$

And similarly for titles purchased only by large budget libraries,

$$\frac{p_z}{u_z} = \frac{p_{z+1}}{u_{z+2}} = \ldots = \frac{p_T}{u_T} \qquad (4)$$

Note that the ratios in (3) and (4) are not necessarily equal.[14] Using these four relationships, prices for titles purchased by all libraries, and for those sold just to large libraries, can be expressed, respectively, as

$$P_i = \frac{B_S * u_i}{\sum_{i=1}^{z} u_i} \quad , \quad P_j = \frac{(B_L - B_S) * u_j}{\sum_{j=z+1}^{T} u_j} \qquad (5)$$

The corresponding profits are

$$\Pi_i = (N_S + N_L) * (P_i - c) - F$$

[14] Generally, since libraries choose the lowest cost/use titles, the ratio associated with the z titles purchased by all libraries will be less than the ratio for the remaining T-z titles (see Appendix B). As budget classes are added to the model, the number of unique cost/use ratios increases as well. This result corresponds to the empirical fact that cost/use ratios vary greatly.

and

$$\Pi_j = N_L * (P_j - c) - F$$

As intuition might suggest, in a given budget class, price and profits are increasing in a journal's quality. On the other hand, the price and profitability of a journal is decreasing in aggregate class quality.

The prices defined by (5) constitute a second period equilibrium under certain constraints on the parameter space. The following proposition summarizes this result.

Proposition 1 – Rank the T titles from highest (title "1') to lowest in use value (title "T"). If prices are defined by (5) and

(A) The z highest use titles are sold to all libraries, the T-z lowest use titles are purchased only by large budget libraries,[15]

(B). $$\frac{N_S * B_S * u_i}{\sum_{i=1}^{z} u_i} \geq \frac{N_L * (B_L - B_S) * u_T}{\sum_{j=z+1}^{T} u_j}$$

where *i* is one of *z* highest use titles,

then for the subgame defined by the preceding conditions, the corresponding prices constitute a Nash equilibrium, provided that

[15] This assumption – that the z highest use titles are sold to all libraries, etc. – is not the only usage ordering for which a second period equilibrium exists. For example, if the converse is assumed, i.e. that the z highest use titles are sold only to large budget libraries, etc., a similar proof can be constructed. However, these alternatives have less empirical support. See McCabe (2000)

(C) $u_{z+1} < u_T + u_E$ (where E is the potential entrant),

(D) $u_1 < u_z + u_E$.

(E). 1. $u_k < u_j + u_T + u_E$, 2. $u_z < u_j + u_T + u_E$

Proof: see Appendix A

Thus, when (1), (2), (3) and (4) are satisfied and given assumptions A and B in Proposition 1, an equilibrium exists. Unfortunately, this equilibrium is not unique. It is easy to show, using similar logic, to demonstrate that many equilibria exist.[16] Nonetheless, the proposed equilibrium is simple, allows us to calculate prices easily, and is generally consistent with the empirical evidence (See McCabe (2000))

Given this period 2 result, I need to determine whether each title's first period strategy choice-- to sell to all libraries or just the large budget libraries -- is optimal. In other words, does the first assumption in Proposition 1 constitute an Nash equilibrium in the initial period? Since higher use titles enjoy relatively more market power, the decision to sell to all libraries must reflect this choice's relative profitability, i.e. that $(N_S+N_L)B_S > N_L(B_L-B_S)$. This inequality corresponds to the observation that in most journal markets the number of "small" libraries far exceeds the population of "large" ones, and that B_L-B_S is not "too" large.[17] For this "ordered" Nash Equilibrium to exist, it must be true that no individual title prefers the alternative sales strategy, i.e. that a higher use titles prefer sales only to the large budget libraries, or that a lower use title prefers sales to all libraries. In the Appendix, sufficient conditions for this first period

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[16] For example, suppose (1) holds but not (2), i.e. at least two different cost/use ratios are observed among the higher cost/use titles. If a title exhibiting a lower ratio raises its price a small amount (to increase its profits), libraries will compare the use value of this title with that of the lowest use, non-deviating title plus the entrant. Since condition *C* implies that the latter pair is always preferred, it is not optimal for any title in this set to increase its price

[17] Empirical support for this inequality can be derived from the National Center for Education Statistics data on library budgets. These data are used in the numerical example discussed below.

equilibrium are provided.

These results can be generalized to the case of multi-journal firms. For any n-journal firm (n > 1), the second period analysis is unchanged (since deviations from the equilibrium in Proposition 1 cannot raise profits). However, in the first period, the n-journal firm needs to consider the pecuniary externalities associated with multiple products. These arise because a journal's profitability is decreasing in aggregate (budget class) quality. This is most obvious in the case of a monopolist that owns 2 journals. In the first 'period, this firm must decide whether to sell both journals to all libraries, just to large budget libraries[18], or assign one journal to each budget class. It is easy to see that the latter strategy is profit-maximizing for any distribution of budgets. If the firm assigns both journals to the same budget class, the 2 products compete for that class's available funds but do not capture any of the funds associated with the other budget class. By assigning one title to each budget class, overall profits increase even if one title's profits decline.[19] More generally, when there are multiple n-journal firms this "diversification strategy" in the first period may not always be profitable, i.e. overall profits may be sacrificed when titles are assigned to both budget classes. The optimal choice for each firm will depend on the relative quality of its titles and that of its competitors, as well as the distribution of budgets. Note that a firm may have an incentive to increase the number of journals it publishes to exploit these potential "synergies." Acquisition of existing titles through merger or the

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[18] This is potentially feasible only if $B_L > 2B_S$; if this inequality is not satisfied then for any pair of journals, (2) and (4) imply that small budget libraries will be able to purchase the lower use title in the pair.

[19] There are two cases to consider: 1. Compared to selling both titles to all libraries, assigning one title to each budget class reduces variable costs and increases revenue, thus increasing the firm's profits. 2. Compared to selling both titles to the largest budget libraries, assigning one title to each budget class increases both variable costs and revenue but since $B_S > c$, profits increase. I also assume that, given the fixed costs associated with each product, the firm prefers to publish both journals.

introduction of new journals can be profitable. I pursue this subject in greater detail in Appendix C.

Case B: Bundling:

Given the same set of assumptions in Case A, e.g. two types of libraries with different acquisition budgets, and T firms, each selling a journal product with use value u_t, etc., it is clear that Proposition 1 can be applied directly to this case.[20] By simply equating *journal product* with *journal bundle* this proposition's results hold. Of course, what is more interesting is how the two cases compare in terms of firm profitability, efficiency, etc. I consider this subject next.

Comparing Cases A and B:

Consider a Case A equilibrium consisting of T n-journal firms where n>1 for at least one firm. If the multi-journal firms own both high and low use titles, these firms will generally assign the two types of titles to separate budget classes. In the bundled case, these same n-journal firms experience a revenue tradeoff. Since price discrimination is not possible, the bundle is sold to a single budget class. Thus these firms must forgo potential revenue from the other budget class. Furthermore, if the bundle is sold to all libraries, these firms' variable costs are higher than in Case A (the low use titles that would only be sold to large budget libraries in Case A are now sold in larger numbers as part of the bundle) . On the other hand, a bundling strategy may raise a firm's market share in its target budget class (measured by aggregate use value), and thus increase the revenue derived from that class. Of course the impact of this tradeoff will depend on the specific distribution of library budgets, journal use values and variable costs as well as the ownership structure.

[20] I assume that the costs associated with an individual title are not affected by the decision to bundle.

Even if one regime is preferred by all (or most) publishers, individual firms may have an incentive to deviate and adopt the alternative distribution strategy. For example, the benefits associated with bundling are amplified when other publishers fail to bundle. Thus, a jointly preferred Case A (or print regime) equilibrium may not survive if bundling is feasible, at least not in a single-period game. However, in a repeated version of the pricing game – a more realistic representation – the jointly preferred regime can survive if participants are sufficiently patient.

Finally, with respect to efficiency, the 1st best outcome is unlikely to be observed. For a specific set of titles, welfare is maximized when the aggregate use value of distributed content is maximized, subject to the constraint that available budget dollars cover costs. If fixed and marginal costs are not too high, this implies that welfare is optimal when each library has access to all titles, not including the potential entrant (this welfare condition is satisfied in the numerical examples described below). Thus for any Case A or Case B equilibrium where one or more titles is purchased by only a subset of libraries, efficiency will not be achieved.[21] Furthermore, since profitability and efficiency may not be perfectly correlated, e.g. Case A may be more profitable for firms but Case B may be more efficient, even a 2nd best outcome may not be achieved.

Price Discrimination

Case C: No Bundling

Since firms price discriminate among libraries each journal product (in this case, an individual journal) competes for each set of customers. This observation allows me to eliminate

[21] Based on my own numerical simulations, the conditions required to support market equilibria in which all titles are sold to each library, except for a potential entrant, are unlikely to be encountered in any existing market. For example, an "all titles" equilibrium could be observed if (1) journals were very similar in use value, (2) the gap between small and large library budgets was small, and (3) the number of small budget libraries greatly exceeded the population of their large counterparts.

the initial stage of the game. And given the same assumptions as in Part 1, this implies that two prices will be associated with each title, one for each of the two customer types. Since prices are customer-specific, the effective distribution of budgets collapses to a single number. Thus, in the single stage of the game, firms choose prices for each of their journals, given their information about the relative quality of all competing products. Again, assume that the same *T+1* titles are available for purchase as before, each owned by a different publisher. Rank the *T+1* titles from highest (title "1') to lowest in use value (title "T+1"). Again, suppose the following two relationships govern pricing,

$$p_{1y} + p_{2y} + p_{3y} + \ldots + p_{ny} \leq B_y \qquad (9)$$

and

$$\frac{p_{1y}}{u_1} = \frac{p_{2y}}{u_2} = \ldots = \frac{p_{ny}}{u_n} \qquad (10).$$

where $n < T+1$, and B_y corresponds to library y's budget. Using these two relationships, prices for the n bundles titles purchased by library y can be expressed as

$$P_{iy} = \frac{B_y * u_i}{\sum_{i=1}^{n} u_i} \qquad (11)$$

Journal i's profits from a sale to small budget libraries $(y = s)$ equals $N_S(P_{iS} - c_i) - F$; sales to large budget libraries $(y = L)$ generate profits of $(N_S + N_L) (P_{iL} - c_i) - F$. Note that journal i will sell to a class of libraries only if profits equal or exceed zero. The following proposition

describes the resulting equilibrium:

Proposition 2

a. *n* titles will be sold to each library, where *n* is the integer that satisfies the following set of inequalities:

$$u_1 < \sum_{i=n}^{T+1} u_i \, , \; u_1 \geq \sum_{i=n+1}^{T+1} u_i \, , \quad n < T+1 \qquad (12)$$

b. If

$$u_n \geq \sum_{i=n+1}^{T+1} u_i \qquad (13)$$

then the prices defined by (11) constitute a Nash equilibrium. If (13) is not satisfied for the n^{th} title, then two possibilities exist for the equilibrium prices:

1. Assume that for *y* = *s* and *y* = *L* average costs for the foreclosed titles are *less* than each of the prices defined by (11) for those titles whose use value does not satisfy (13). Then the equilibrium prices for the m titles (m < n) for which (13) is satisfied are equal to

$$P'_{iy} = \frac{(B_y - \Omega) * u_i}{\sum_{i=1}^{m} u_i} \qquad (14)$$

where Ω measures the amount of *y*'s budget allocated to the *w* titles for which (13) is not

satisfied. For each of these titles, the optimal price, p_w, is just less than the sum of the average costs of the subset of foreclosed titles whose corresponding aggregate use value just exceeds u_w. That is,

$$\Omega = \sum P_w \,,\; P_w = \sum_{i=n+j}^{T+1} AC(i) - \varepsilon \,,\quad AC(i) = \frac{F}{N_S + N_L} + c \qquad (15)$$

where $n+j$ is defined by the following inequality

$$\sum_{i=n+j+1}^{T+1} u_i \le u_w \le \sum_{i=n+j}^{T+1} u_i \,,\quad j \ge 1 \qquad (16)$$

2. Assume that for $y = s$ and $y = L$ the average costs for the foreclosed titles are *greater* than each of the p_w. Then for all titles purchased, the prices defined by (11) constitute a Nash equilibrium.[22]

Proof: See Appendix A

Proposition 2 demonstrates that foreclosure of (lower use) titles may occur when price discrimination forces all titles to compete for sales to each class of libraries. These foreclosed titles are purchased under the conditions of Proposition 1. Furthermore, if the use value of these foreclosed titles is large enough, i.e. (13) is not satisfied, they constrain the prices of some of the titles that are purchased (15).

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[22] Note that it is possible that average costs for the foreclosed titles are less than some but not all of the p_w for $y = s$ *and* $y = L$. Since the p_w for $y = L$ exceed those for $y = s$, this situation may arise, for example, when average costs are relatively large. If so, then the p_w for the $y = s$ libraries will be defined by (11) and those for the $y = L$ libraries by (15). Note also that in the latter case, the denominator in the average costs relationship defined in (15) equals N_L.

Again, these results can be generalized to the case of multi-journal firms. There are two cases to be considered. First, if none of a firm's titles are foreclosed then there are no additional benefits associated with owning multiple titles. Since all titles are sold to both types of libraries there are no pecuniary externalities to be exploited. Second, if one or more of a firm's titles are foreclosed in equilibrium it is possible to increase profits by permitting sales of these titles (the firm's profits increases as its share of purchased use value rises). This can be achieved in equilibrium if other firms do not have the ability (and thus the incentive) to continue foreclosing these titles *and* if none of the remaining foreclosed titles have higher use values than the affected titles. For example, suppose a firm owns the highest use title(s) in the population as well as the highest use title that would be foreclosed in the equilibrium described by Proposition 2. In this case, the firm's profits would increase if (1) it did not foreclose the latter title and (2) no other firm owning a relatively high use title had the ability to foreclose this title. Note that if the otherwise foreclosed title's use value is not the highest among those in the set of foreclosed titles, then an attempt to sell this title would fail. A higher use title in this set would always be preferred by libraries at the same price.

Case D: Bundling (the digital environment)

Given the same set of assumptions in Case C, e.g. price discrimination, T+1 firms, each selling a journal product with use value u_t, etc., it is clear that Proposition 2 can be applied directly to this case. Again, by simply equating *journal product* with *journal bundle* this proposition's results hold. Of course, what is more interesting is how the two cases compare in terms of firm profitability, efficiency, etc. I consider this subject next.

Comparing Cases C and D:

Unlike the comparison of Cases A and B, where the decision to bundle involves a revenue

tradeoff, the analysis of a C versus D scenario is simpler since the existence of price discrimination eliminates this tradeoff. Ignoring costs for the moment, it is clear that firms with the largest share of aggregate use value will prefer bundling. By bundling they can avoid foreclosure of any of their lower use titles as well as benefit from the foreclosure of firms with small shares. And even if the smaller share firms prefer the non-bundled environment of Case C, their dominant strategy in this situation is to bundle as well (since bundling never lowers revenue). And if fixed and variable costs are not too large, this bundling strategy will also be associated with higher profits for the largest share firms (if these costs are large, a bundle that includes many low use titles that are otherwise foreclosed in a Case C equilibrium, will tend to reduce profits).

If costs are high, and (the non-foreclosed) firms jointly prefer the non-bundled regime, individual firms may still have an incentive to deviate and bundle. The analysis of this case is the same as for the A versus B comparison – if firms are patient enough then the non-bundled equilibrium will be observed in the repeated version of the game. Finally, since one or more titles are always foreclosed, the 1st best outcome is never achieved. Note, however, that compared to cases A and B, the *average* aggregate use value of library collections may be higher when price discrimination is observed. This occurs so long as the degree of foreclosure is not too great. If so, and since all titles compete for sales to each library class, the use value of the small budget library collections increases. By contrast, the large budget library collections suffer a decline in quality if there is any additional foreclosure.[23]

[23] However, even though the average collection may increase in value, since the existence of price discrimination leads to greater foreclosure, overall scientific diversity declines. This suggests that any careful welfare comparison would need to explore how libraries and their user communities weigh these two dimensions.

Comparing the Four Regimes

The preceding analysis suggests that unbundled, non-discriminatory sales (Case A) are likely to be preferred by firms when variable costs are relatively high. This is because the absence of price discrimination reduces the number of subscriptions that are distributed and this in turn increases profits by lowering costs. Conversely, when these variable costs are low, bundled sales (Cases B and D) will tend to be preferred. Of these two alternatives, Case D is likely to be more attractive to the largest firms because the cost penalty associated with price discrimination is low compared to the benefits of foreclosure. And if the largest firms choose to price discriminate then the remaining firms' best response is to do so as well.

3. A Numerical Example

- There are six journals purchased by libraries that vary in their use value, u, with values of 12, 12, 10.2, 8, 6.2, and 6. The potential entrant title has a use value of 4.1.
- There are five publishers. Firm 1 controls one of the "12" titles as well as journal 8; firm 2 controls the remaining 12 journal and title 6; firm 3 owns title 10.2; firm 4 owns title 6.2; firm 5 owns the potential entrant.
- For each journal there are fixed costs of $100,000 (these costs correspond to the "first copy" costs for each issue of a journal – reviewing manuscripts, editing, typesetting, etc.).
- The variable or marginal costs for each subscription are set at two different values (these costs include reproduction, distribution and customer support costs). Two values are considered – $450 and $45.[24]
- Two types of library budgets, small and large, with values of $5,000 and $12,500 respectively.

[24] According to Tenopir and King (2000), the primary impact of the transition from print to digital distribution is a reduction in variable costs. Although certain fixed costs decline with this change, e.g, typesetting costs, other fixed costs tend to increase, e.g. copy editing. Although the fixed and variable cost parameters employed here are similar in magnitude to those reported in Tenopir and King, their specific values do not represent any actual cost data.

- 600 libraries have small budgets, 150 have large budgets.[25]

Based on these assumption and using Propositions 1 and 2, I calculated the equilibrium prices, cost/use ratios, quantities and profits for each of the four regimes, first for MC=$450 and then MC=$45. The results are reported in Tables 1 and 2. Note that the cost/use ratios are lower for purchases made by the small budget libraries. As expected, when MC=450, the three largest firms – 1, 2 and 3 – clearly prefer Case A to any of the other regimes.[26] Case D is the second best outcome for the three largest firms; these same firms disagree about the 3rd and 4th ranked regimes (cases B and C). From the perspective of firms 1,2 and 3, Case C's poor showing occurs for two reasons: (1) firm 2's lower use title - 6 - is foreclosed, (2) since firm 4's single title is more valuable than 2's foreclosed title, firm 1 and firm 3's profits are reduced, compared to Case D. Only firm 4 would prefer a non-print regime, namely Case B. However, it has no ability to influence its fate. Note that although title 6.2 (title 6) is foreclosed in Case D (Case C), average collection quality is higher in the price discrimination regimes than in the non-price discrimination regimes (but scientific diversity is reduced).

As expected, the digital regime (case D) is preferred by the largest firms when MC=45.

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[25] The relative size of the budgets and the numbers of small and large budget libraries were chosen to resemble the distribution of the world's largest research libraries (the absolute size of the budgets are much smaller due to the small number of titles in the example). For example, using 1998 the U.S. National Center for Education Statistics' data on library budgets for serial titles, I calculated the mean value of the 50 largest budgets ($4.5 million), and of the next 200 largest budgets ($1.7 million). In 1998, these 250 libraries spent more than twice as much on serials ($568 million) as the remaining 2500 libraries that reported spending more than $1000 on serials (a total of $254 million). Furthermore, I assume that U.S. journal sales constitute about 1/3 of total world sales. Then, if the research library budgets in other parts of the world exhibit similar characteristics, the demand-side assumptions in the example are consistent with these statistics.

[26] If the underlying 2-period "stage" game is not repeated indefinitely, either firm 1 or 2 would have an incentive to bundle to increase its profits. I assume the firms are patient enough to prefer the jointly preferred Case A outcome.

Firms 1 and 2 prefer to both bundle and price discriminate; the remaining firms could not block this choice. Furthermore, firm 4 is foreclosed in this scenario. In contrast the print regime (case A) is the least attractive option for firm 1, and the second worst choice for firm 2. And although firms 1 and 2 consider Case B to be second best (as expected), firm 3 could always choose to price discriminate and almost double its profits while lowering 1 and 2's profits dramatically. Again, Case C performs poorly for the same reasons as above.

4. Discussion and Directions for Future Research

This paper offers a model of journal pricing that incorporates the behavior of libraries in a market populated by multiple titles and firms. Two variants of this model are used in the analysis of four distribution regimes that differ with respect to the ability or inability of publishers to (1) price discriminate among customers and (2) bundle their journals. One of these regimes – no bundling or price discrimination – corresponds to the print environment that has been observed in recent decades. Another regime – bundling and price discrimination – best describes the digital environment that is expected to replace the print regime in the very near future. The models and associated numerical simulations demonstrate that a sharp decline in marginal costs can explain the ongoing shift from the print to digital regime. The models also provide a mechanism that can account for the price impact of recent journal publisher mergers.

Of course, these models are not complete or exhaustive in their treatment of the determinants of journal pricing and demand. For example, I have treated journal use value as exogenous throughout the paper. Although this is most likely a reasonable assumption in the short run, i.e. two or three years, over a longer period of time, any significant change in sales may feed back and influence a title's actual use. That is, in the long run there may exist a positive relationship between the number of subscriptions and journal use that I have ignored here. Thus, substantial price increases may have long term effects that erode profitability.

This potential tradeoff may explain why publishers do not fully exploit the inelastic demand of their customers (see McCabe (2000) for some empirical evidence on demand elasticities).

Other possibilities for future work include (1) the introduction of asymmetric information and/or uncertainty, e.g. publishers may not have complete information on library journal product valuations, library budgets, etc., (2) an attempt to model this market using a continuous rather than discrete approach. If successful, the analytical conclusions would be more robust, and less dependent on numerical simulations, (3) an effort to explore the potential endogeneity of library budgets and its impact on pricing. Anecdotal evidence suggests that budgets in year t are set partially in response to expectations about prices in that year, (4) an analysis of the behavior of commercial publishers in a mixed market, i.e. one in which non-profit publishers compete successfully with their for-profit counterparts. In this paper I have implicitly assumed that non-profits publishers are passive agents, absorbing some fixed amount of available budget dollars, and (5) an examination of the structural market changes that may occur as the transition to digital distribution is completed. As expected, publishers have begun negotiating contracts that are customer-specific and typically include access to the firm's entire journal portfolio. Second, librarians themselves are aware that signing such a "Big Deal" contract reduces their bargaining power and enhances the publishers' market power. Third, actions taken by libraries and scholars in the past few years to create free and comprehensive archives of scientific papers as well as new, alternative non-profit e-journals can be seen as a response to the threat of the Big Deal (see Frazier (2001) for evidence on each of these points).

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Table 1 – High Marginal Costs, MC=$450 (in all cases, the potential entrant is not purchased).

Case A – No Price Discrimination, No Bundling ("print regime")						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	750	1,754	146	878,289	1,156,334
1	8	150	2,970	371	278,045	
2	12	750	1,754	146	878,289	1,044,948
2	6	150	2,228	371	166,658	
3	10.2	750	1,491	146	680,921	680,921
4	6.2	150	2,302	371	177,797	177,797
Case B – No Price Discrimination, Bundling						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	750	2,632	132	1,088,684	1,098,684
1	8	750				
2	12	750	2,368	132	901,316	901,316
2	6	750				
3	10.2	150	4,665	457	532,195	532,195
4	6.2	150	2,835	457	257,805	257,805

Table 1 continued

Case C – Price Discrimination, No Bundling						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	600	1,240	103	393,802	1,139,463
1	12	150	3,099	258	377,376	
1	8	600	826	103	145,868	
1	8	150	2,066	258	222,417	
2	12	600	1,240	103	393,802	771,178
2	12	150	3,099	258	377,376	
2	6	Foreclosed	NA	NA	NA	
3	10.2	600	1,054	103	282,231	589,876
3	10.2	150	2,634	258	307,645	
4	6.2	600	640	103	34,298	186,983
4	6.2	150	1601	258	152,686	
Case D – Price Discrimination, Bundling (“digital regime”)						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	600	2,075	104	544,813	1,147,822
1	8	600				
1	12	150	5,187	259	603,008	
1	8	150				
2	12	600	1,867	104	420,332	945,539
2	6	600				
2	12	150	4,668	259	525,207	
2	6	150				
3	10.2	600	1,058	104	284,855	594,139
3	10.2	150	2,645	259	309,284	
4	6.2	Foreclosed	NA	NA	NA	NA

Table 2 - Low Marginal Costs, MC=$45. (in all cases, the potential entrant is not purchased).

Case A – No Price Discrimination, No Bundling ("print regime")						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	750	1,754	146	1,182,039	1,520,834
1	8	150	2,970	371	338,795	
2	12	750	1,754	146	1,182,039	1,409,448
2	6	150	2,228	371	227,408	
3	10.2	750	1,491	146	984,671	984,671
4	6.2	150	2,302	371	238,547	227,408
Case B – No Price Discrimination, Bundling						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	750	2,632	132	1,706,184	1,706,184
1	8	750				
2	12	750	2,368	132	1,508,816	1,508,816
2	6	750				
3	10.2	150	4,665	457	592,945	596,375
4	6.2	150	2,835	457	318,555	318,555

Table 2 continued

Case C – Price Discrimination, No Bundling						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	600	1,504	125	795,456	1,522,807
1	12	150	4,136	345	593,601	
1	8	600	357	45	107,000	
1	8	150	357	45	26,750	
2	12	600	1,513	125	795,456	1,389,057
2	12	150	4,136	345	593,601	
2	6	Foreclosed	NA	NA	NA	
3	10.2	600	1,278	125	649,471	1,160,636
3	10.2	150	3,515	345	500,548	
4	6.2	600	357	58	107,000	133,750
4	6.2	150	357	58	26,750	
Note: prices for titles 8 and 6.2 are constrained by the foreclosed titles, 6 and 4.1 (see proposition 2), since AC are low. As a result, their prices are common for both sets of libraries						
Case D – Price Discrimination, Bundling (“digital regime”)						
Firm	Use Value	# of Subscript	Price($)	Cost/Use	Profits($)	Firm Profits
1	12	600	2,075	104	1,030,813	1,755,322
1	8	600				
1	12	150	5,187	259	724,508	
1	8	150				
2	12	600	1,867	104	918,780	1,553,039
2	6	600				
2	12	150	4,668	259	654,488	
2	6	150				
3	10.2	600	1,058	104	527,855	897,899
3	10.2	150	2,645	259	370,034	
4	6.2	Foreclosed	NA	NA	NA	NA

Appendix A:

Proof of Proposition 1: Consider a drop in price by some title *i*. If *i* belongs to the set of z titles sold to all libraries, then this change has no effect on the title's demand but does lower its profits. However, if *i* belongs to the T-z lower use titles, the impact of this price change depends on the distribution of journal use values among the two sets of titles. Since *i*'s use value does *not* exceed that of any titles sold to all libraries (assumption A) its attempt to displace higher use titles by dropping its price will leave the affected libraries with unused funds. Since I assume that libraries wish to maximize use value, these libraries will prefer to exhaust their budgets and choose the z highest use titles. Thus, *i*'s strategy is not profitable.

To show that a price in increase is unprofitable, I need to consider the role of potential entry. Consider first the *T-z* titles sold to large budget libraries. With the exception of the lowest use title in this set (title *T*), [27] a small price increase by one of the higher use titles, *j*, may be profitable in lieu of an entry threat. As in the case of a price decrease, a price increase disrupts the normal operation of the libraries' cost/use criterion. Although title *j* has a higher cost/use ratio than the other *T-z-1* titles, each library prefers the highest value set of titles. For a small price increase, the preferred set of titles includes title *j*, and excludes journal *T*. To eliminate this possibility (that is, for (2) and (4) to hold), it must be the case that (C) is true. So long as *E*'s price does not exceed *j*'s "equilibrium" price (as determined by (2) and (4)), the libraries' preferred set of titles then includes *T* and *E*, and excludes *j*. Since prices are announced simultaneously in the second period of the game, this condition can be satisfied as follows: Define E's price as a function of the other title's announced prices - if a price deviation is observed, let E's price equal the highest non-equilibrium price; otherwise E's price equals some arbitrary positive number.[28]

For the *z-1* highest value titles sold to all libraries, the analysis of a price increase is similar. Again, a price increase by one of these titles, *k*, may be profitable in lieu of an entry threat.[29] Faced with a price increase by title *k*, the small and large budget libraries would respond differently. In each case the relevant lowest use equilibrium title would not be selected – the small budget libraries would drop title *z*, and their larger counterparts would cancel title *T* [Note that the cost/use criterion rules out the possibility that *k*'s price increase would result in *k* being purchased only by the small budget libraries, since what the latter purchase is always a subset of the large budget library portfolios.]. To eliminate this possibility

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[27] If the lowest use title in this set raises its price, the affected (large budget) libraries will be forced to cancel one or more titles. Since the libraries will always prefer purchasing the remaining T-z-1 titles, this low use title is dropped and thus the latter's strategy is not profitable.

[28] A less elegant option is to constrain E's price from being higher than the equilibrium price of the second lowest use title in the set of purchased titles.

[29] In contrast to the previous case, if the lowest use title in this set attempts a price increase, the large budget libraries may displace one of the titles that they alone purchase and keep the deviating title. However, the small budget libraries will drop this title.

(that is, for (1) and (3) to hold), it must be the case that entry deters any price deviation. First, consider the small budget libraries. For title z and E to be preferred to journal k, (D) must hold. Despite the loss of sales to the small budget libraries, it is possible for title *k* to increase its profits if purchased only by the large budget libraries. If k's price increase was equal to or smaller than T's price, then assumption (B) insures that k's profits decline.[30] [Note that this result does not rely on entry deterrence, i.e. $u_k > u_T + u_E$ may be true. Although this result could also be achieved by concluding that $u_k < u_T + u_E$, this condition would place greater restrictions on parameter values than the combination of assumptions (B) and (E1) (this can be demonstrated in the numerical example)]. To eliminate the possibility that k's price increase is larger than T's price, (E1) must hold. That is, the large budget libraries would cancel title *k* and substitute the entrant title. Finally, if z's price increased, the small budget libraries would always prefer the remaining z-1 titles (see footnote 31); if the price increase was equal to or smaller than T's price, z's profits would decline (assumption (C). If the price increase was larger than T's price, it must be the case that the large budget libraries would cancel z ((E2)).

Conditions for a first period Ordered Nash Equilibrium:
For this "ordered" Nash Equilibrium to exist, it must be true that no individual title prefers the alternative sales strategy, i.e. that a higher use titles prefer sales only to the large budget libraries, or that a lower use title prefers sales to all libraries.[31] In the case of higher use titles this implies,

$$\Pi_i > N_L \left[\frac{\frac{(B_L - B_S) * u_i}{T}}{[\sum_{j=k+1} u_j] + u_i} - c \right] + \Delta_i \qquad (17)$$

where the second term on the right hand side, Δ_i, corresponds to the additional profits that will accrue to *i* if it is able to displace one or more low use titles in period 2 (since assumption C in Proposition 1 does not necessarily hold). For the lower use titles, the corresponding inequality is

$$\Pi_j > (N_S + N_L) * \left[\frac{B_S * u_j}{[\sum_{i=1}^{z} u_i] + u_j} - c \right] - \Delta_j \qquad (18)$$

where the second term on the right hand side, Δ_j, corresponds to the loss in profits that j will experience if it is displaced by one of the high use titles in period 2 (since assumption D in Proposition 1 does not necessarily hold). Note that displacement here refers to cancellation by

[30] The left hand side of the inequality in assumption B corresponds to the decline in profits associated with the loss of sales to small budget libraries and the right hand side equals the increase in profits from sales to large budget libraries.

[31] Note that the "deviations" considered here differ from those in the second period, that is, they do not involve displacement of any titles.

the small budget libraries. Since this alternative strategy involves a price decrease to attain a lower cost/use ratio – see below – and because assumption C holds for low use titles, the large budget libraries would continue to purchase title *j*.

Since it is not possible to generalize about Δ_i and Δ_j (without placing further restrictions on the parameter space) one strategy for simplifying this first stage analysis is to assume that both equal zero, and then later check whether (17) and (18) are satisfied in any numerical simulations. Suppose then that $\Delta_i = \Delta_j = 0$, and that c = 0, then combining (17) and (18) yields the following equilibrium condition,

$$\frac{[\sum_{j=z+1}^{T} u_j] + u_i}{\sum_{i=1}^{z} u_i} > A > \frac{\sum_{j=z+1}^{T} u_j}{[\sum_{i=1}^{z} u_i] + u_j} \qquad (19)$$

where

$$A = \frac{N_L (B_L - B_S)}{(N_S + N_L) B_S} < 1$$

The LHS inequality in (19) is simply a re-arranged form of (17); the RHS inequality is based on (18). For a Nash equilibrium to exist in this stage, (19) must hold for all journals. Furthermore, if (19) holds for the *zth* and *Tth* journals, it is easy to demonstrate that (19) is satisfied for all titles. To see this, note that for the zth journal the LHS is at its *minimum* value ($u_z < u_i$ for all i < z); for the Tth journal, the RHS ratio is at its *maximum* value ($u_T < u_j$ for all j < T). If (19) holds for these two firms, then it is satisfied in all instances. When c has a positive value, a similar analysis can be performed.[32] Thus, searching for an "ordered" equilibrium involves first checking that the RHS inequality holds for the Tth journal and then identifying the marginal high quality journal for which the LHS inequality is satisfied.

Proof of Proposition 2:

a.) Consider a drop in the price charged by one of the purchased titles, *i*, to library *y*. This change has no effect on the bundle's demand but it does lower profits. Now consider a small price increase by the highest value bundle, i=1. If all available titles were purchased, then library y will choose to displace the lowest value title, T+1, rather than drop title 1 (see the proof of proposition 1 for similar reasoning regarding the entrant title, E). Now, if the T highest value titles are purchased in equilibrium, then it must be the case that $u_1 < u_T + u_{T+1}$; otherwise, title 1 would have an incentive to raise its price a small amount and displace title T. If this inequality is

[32] When marginal costs are positive, (17) and (18) cannot be combined to generate (19). Each inequality needs to be considered separately. In that case, I can show that if (17) is satisfied for the z^{th} title, then it is satisfied for the higher use titles; the same is true if (18) is satisfied for the T^{th} journal.

not satisfied, then the same reasoning can be applied to equilibria consisting of T-1 titles, T-2 titles, etc., until the respective inequalities are satisfied.

b.) Suppose (13) is satisfied for *n*. Since (12) is also satisfied for this *n*, I can show that a Nash equilibrium in prices exists that is described by (11). The proof is analogous to the discussion in proposition 1 of pricing by titles purchased by large budget libraries, and is thus omitted here.

If (13) does not hold for the n^{th} title but (12) is still satisfied for n, the implications for pricing may differ.

1. First, consider the m highest use titles for which (13) does hold. Given the dollars available in library y's budget, $B_y - \Omega$, I can show that a Nash equilibrium in prices exists that is described by (14). Again, the proof is analogous to the discussion in proposition 1 of pricing by titles purchased by large budget libraries, and is thus omitted here. Next, consider each of the *w* titles for which (13) is not satisfied. The prices in (15) reflect Bertrand competition between each of these titles and the relevant non-purchased titles defined by (16). Recall that library y's objective is to maximize the use value of its collection. Given P_i and P_w, if library y purchases a given set of otherwise foreclosed titles, its collection's aggregate use value will decline. To see this, suppose there is just one *w* title priced at P_w. If library y purchases the foreclosed titles their cost exceeds P_w, forcing library y to not only displace z but also the m^{th} title, thus reducing the value of y's collection. Conversely, if *w* 's price equals or exceeds that of the foreclosed titles, library y will purchase the latter and increase its collection's use value. With two or more z titles the argument is similar and is omitted here (The only difference in the argument is that purchase of a set of foreclosed titles forces library y to displace two *w* titles, reducing the value of its collection).

2. Since the P_w are not constrained by the foreclosed titles, prices are defined by (11). See part b above.

Appendix B:

Claim: In the cases where no price discrimination is permitted, titles sold to all libraries exhibit lower cost/use values than those sold only to large budget libraries.

Using the price equations for titles sold to all libraries and those sold only to large budget libraries (see (5)), I want to show that

$$\frac{B_S}{\sum_{i=1}^{z} u_i} < \frac{(B_L - B_S)}{\sum_{j=z+1}^{T} u_j} \qquad (20)$$

Proof: Re-arrange (20) so that the summation terms are on one side of the inequality, and multiply both sides by the ratio $(N_S + N_L)/N_L$. The resulting inequality is

$$\frac{B_S \cdot (N_S + N_L)}{N_L \cdot (B_L - B_S)} < \frac{\sum_{i=1}^{z} u_i}{\sum_{j=z+1}^{T} u_j} \cdot \frac{(N_S + N_L)}{N_L} \qquad (21)$$

The LHS of this inequality corresponds to the reciprocal of A in (19). From (19) I know that

$$\frac{B_S \cdot (N_S + N_L)}{N_L \cdot (B_L - B_S)} < \frac{\sum_{i=1}^{z} u_i + u_j}{\sum_{j=z+1}^{T} u_j} \qquad (22)$$

Thus, (20) is true when the RHS of (22) is less than the RHS of (21). After some simplifying steps, it is easy to see that this latter requirement is met when the following inequality is satisfied:

$$N_L \cdot u_j < \sum_{i=1}^{z} u_i \cdot N_S \qquad (23)$$

Thus (20) holds if $N_S > \alpha\ N_L$, where α (<1) is equal to $u_j \,/\, \sum u_i$. Of course, this result depends on the assumption that marginal costs, c, equal zero (since (19) must hold). When c>0, (21) needs to be checked numerically. Finally, if price discrimination is possible, and the same set of titles is sold to each budget class, then it is immediately clear that cost/use values are lower for small budget libraries.

Appendix C:

Merger Analysis:

In the market for journals, firm size can be measured in at least two ways – the amount of use value controlled by a firm and the number of journals in a firm's portfolio. Growth in either dimension allows a firm to better exploit strategic opportunities, and thus increase revenues and profits. To understand this idea in the case of mergers, consider first an example based on one of the non-price discrimination regimes, e.g. the print regime. Assume again the market structure described in the numerical example. Now suppose firm 1 purchases the potential entrant, with use value 4.1, and then assigns it a price equal to infinity in period 2 (or any price large enough to deter its purchase). If this strategy is anticipated by the other firms, then in period 2, firm 1 will set a higher price for title 8 that results in foreclosure of firm 2's low use title (with a use value of 6). Given firm's 1 strategy vis-a-vis its acquired title, the newly foreclosed title will now assume the role of the potential entrant. Note that none of the titles sold to all libraries (with use value 12, 12 and 10.2) will alter their behavior. The result is that prices and profits increase for firm 1 as well as firm 4's title (with use value 6.2).

This merger raises profits (prices), of course, because a journal's profitability (price) is decreasing in aggregate class quality. In the above example, foreclosure of title 6 raises profitability for the remaining pair of titles sold only to the large budget libraries. Another strategy that is similar to the above case involves "journal jumping." For example, if a merger affects titles sold to all libraries, it can be profitable to sacrifice the profits of one or more of these titles (by re-assigning them to the large budget libraries) so that the remaining general circulation titles face less competition.[33] Note that the profit-increasing mergers described here are generally associated with a decline in the average use-value of library collections.

When price-discrimination is possible the only profit-increasing strategy involves foreclosure. Again, assuming the same market structure, as well as bundling (the digital regime), suppose firm 1 (titles 12 and 8) purchased any one of the other firms in the market (including the potential entrant). It is easy to show that this strategy would increase profits for the merging firms (by increasing the amount of foreclosed use value). Furthermore, if the merged firm controls more than half of the market's aggregate use value, e.g. due to a merger of firm 1 and 3, all remaining titles are foreclosed. This results not only in less scientific diversity but also a decline in the quality of the average library collection. In a market place populated by thousands of titles, this "super merger" effect is unique to the digital regime.

[33] This strategy is not available to any of the firms in the numerical example. Furthermore, some firms may not have any profit-increasing merger opportunities, e.g. firm 3 (title 10.2) in the above example.