Price Discrimination and Copyright Law: Evidence from the Introduction of DVDs

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Abstract

This paper examines the welfare effects of market segmentation using the example of the video rental and sales markets (both VHS and DVD formats). I consider a market with two types of buyers: institutional and individual buyers. Institutional buyers rent the good to low-value individuals, while relatively high-value individuals purchase the good directly rather than renting it. Copyright law in the U.S. effectively prevents market segmentation according to use of the product. As a result, rental and sales markets for VHS cassettes are traditionally segmented by pricing VHS cassettes intertemporally: first setting a very high price for the institutional buyers, and lowering the price six months later for sales to end-users. For selected products, especially children's movies, this two-tiered pricing strategy is discarded in favor of an immediate low price to stimulate early sales to end-users. When pricing the DVD format over the past three years, firms have chosen to discard the two-tier pricing model completely. Using data on the rental and sales activities of video rental stores for both VHS and DVD formats, I estimate a model of intertemporal price discrimination which rationalizes the use of such different pricing policies for the same movie on two different formats. I use the estimated parameter values to predict whether or not the elimination of intertemporal price discrimination will remain the optimal strategy as DVD hardware penetration evolves, and to estimate the effects of the restrictive copyright law for firms and consumers.

1 Introduction

Following the invention of the VCR, motion picture studios examined the possibility of selling videocassette tapes of movies directly to consumers. In 1979, Paramount began licensing Fotomat to sell videocassette tapes of its movies, and soon discovered that retailers were purchasing the tapes from Fotomat stores and renting them out at their own stores. This was (and is) legal under the U.S. Copyright Act of 1976, which stipulates that an owner of a legally-owned copy of a creative production has the right of "first use." This stipulation, commonly referred to as the Right of First Sale Doctrine, invokes copyright jurisdiction only upon the first sale of videocassette tapes, so that subsequent use (including rentals) does not generate income to the copyright holder.

In fact, in 1977, MCA/Universal and Disney had jointly sued the Sony Corporation, which created and owned the rights to Betamax hardware, over alleged lost revenues from home recordings of broadcast television programs. In 1984, the Supreme Court voted five-to-four in favor of Sony in *Universal v. Sony*. The decision permitted home videotaping of copyrighted programs without royalty payments, but was more broadly interpreted to uphold the First Sale Doctrine, and the case paved the way for the emerging video rental retail industry (Childs, 1992).

The importance of this doctrine for the industry is to effectively strip movie studios of any ability to price discriminate between institutional and individual users in the video rental market, since any organization can purchase videocassette tapes as an individual user and legally rent them out. Thus, movie studios in the U.S. do not charge different prices to video retail stores and individual buyers. In contrast, many other countries specify their copyright law so that copyright holders can restrict use of the product after first sale (i.e., Australia and the United Kingdom). When selling a movie to the video rental market in these countries, studios do in fact charge very different prices to the two types of buyers.

Historically, movie studios typically have dealt with the copyright restrictions in the U.S. by simply setting a very high price for videocassettes (on VHS format). Retail prices for VHS tapes currently range from around $99.95 to $107.95, with price variation usually seen only at the studio level (but not across titles within a studio). Approximately 4 - 6 months after its initial release, the studio re-prices the movie for "sell-through." At this time, the retail price falls to the range of $19.99 - $26.99 and videocassettes turn up for direct sale to consumers at mass merchandisers and video stores. Wholesale prices facing retailers are in

the range of \$65 - \$70 in the first period, and then fall to \$10 - \$15 after the sell-through re-pricing. Approximately 90 percent of all movie titles on the VHS format are priced in this way. An inefficiency of such intertemporal price discrimination is the occurrence of double-marginalization and understocking in rental markets, as retailers purchase only a small quantity of tapes at the high "rental" price. An important contractual change in the industry in the late 1990's and early 2000's has involved the use of revenue-sharing contracts to mitigate this source of inefficiency, and many studios are now participating in such programs. (See Dana and Spier (2002), and Cachon and Lariviere (2002), for theoretical analyses of such contracts, and Mortimer(2002) for an empirical analysis of the actual contracts.)

As mentioned, this two-tiered "rental pricing" strategy (either in conjunction with revenue-sharing, or not) is used for approximately 90 percent of all titles on VHS. For the remaining 10 percent, the initial rental window is forgone in favor of generating early direct sales to consumers. For these titles, studios set a retail price in the range of \$19.99 - \$26.99 immediately upon the first release. Wholesale prices are again in the range of \$10 - \$15, and both rental stores and individual users may purchase at these low prices. This practice, referred to as "sell-through pricing," is typically used for children's titles, and occasionally it is used for huge blockbuster titles, especially movies with 'teenager' appeal. Examples of sell-through priced movies include *Blair Witch Project, Titanic,* and *Antz.* Revenue-sharing contracts are typically not used on sell-through priced titles.

With the introduction of the DVD format, studios have adopted sell-through pricing for a movie's DVD release, even as they maintain a rental-pricing strategy for the same-day release of the movie's VHS format. For example, *The Green Mile* was initially released with a VHS price of \$107.95 and a same-day DVD price of \$24.95. There are two possible explanations for this major change in the pricing policy of the new format. On one hand, the format itself may transform the nature of the product to such a degree that the optimal pricing strategy no longer involves a rental window. In this case, one would expect that sell-through pricing will remain the standard for pricing in the DVD market. On the other hand, a sell-through pricing strategy could be used in the initial phase of DVD hardware evolution in order to stimulate direct sales to "high-value" early adopters, and to take advantage of any novelty effect that new hardware adoption has on purchases of software. In addition, the use of sell-through pricing for the DVD format may help to price discriminate between

institutional and individual buyers initially, if most renters are still using the VHS format. In this case, one would expect the growth of rentals to outpace the growth of sales over time as hardware adoption progresses to "low-value" movie viewers. As more low-value consumers adopt DVD hardware and choose to rent rather than purchase on the DVD format, upstream firms (movie studios) should again adopt a rental-pricing strategy in order to discriminate between the institutional and individual purchasers.[1]

An important motivation for the adoption of sell-through pricing of DVDs in the U.S. market is a restriction effectively imposed by the U.S. Copyright Act through the First Sale Doctrine. In many other countries, DVDs are simply sold at different prices to rental stores and individual buyers simultaneously. This paper seeks to answer the following questions. First, what effect does the restriction of the U.S. Copyright Act have on consumer and producer surplus? Answering this question requires a comparison of current estimates of welfare to estimates of welfare under the case in which direct market segmentation (between institutional and individual buyers) is allowed. The second question is, what are the relative welfare effects under the two current pricing strategies? In other words, will consumers be made better or worse off if rental pricing is adopted for DVDs? Also, should studios choose to adopt rental pricing, or continue to use sell-through pricing as DVD hardware adoption continues to evolve? These questions require that one compare estimates of welfare under rental and sell-through pricing regimes.

Although the paper pertains to the effects of copyright law for firms and consumers, it also relates to the growing empirical literature on price discrimination, especially in the comparison of rental versus sell-through pricing. The most relevant previous study on price discrimination is Leslie (2002), which examines the welfare effects of both second- and third-degree price discrimination in Broadway theater. Leslie examines an industry where both types of price discrimination are used; he seeks to empirically estimate the welfare effects of price discrimination, as the direction of the effects theoretically are ambiguous. Again, in the current paper, legal restrictions prohibit third-degree discrimination. I examine the effects of second-degree discrimination and compare these to results of two alternatives: market segmentation (which addresses the question of the effects of copyright law), and

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[1]An alternative explanation may be that piracy is easier on the digital DVD format, and a sell-through pricing strategy is aimed at discouraging piracy. The effects of piracy, however, are complicated: they depend on the upstream firm's ability to monitor piracy both by individuals and by video rental stores. While piracy may be easier with the digital format, monitoring capabilities-especially for video rental stores-have also improved dramatically in recent years.

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no price discrimination (ie., rental versus sell-through pricing). Thus, I hope to provide further empirical evidence on the welfare effects of price discrimination in the context of a very different institutional setting.

The role of purchase and rental markets to segment high- and low-value consumers has also been studied theoretically by Varian (2000), who also provides a historical background of the video rental industry in Varian and Roehl (2000). Varian (2000) derives conditions under which pricing for a rental market, or pricing for direct sale, will be more profitable for the owner of an information good. He identifies three factors that play a role in determining the more profitable strategy: transactions costs of renting compared to the marginal cost of production, the number of times content is viewed, and the ability to use a rental market to segment high- and low-value consumers. The model I derive is very similar in spirit–the main difference is that my model also incorporates intertemporal segmentation. Thus, in the absence of contemporaneous market segmentation that might be achievable under a less restrictive copyright law, the choice becomes whether to price discriminate intertemporally or not.

The paper provides a description of the industry and data sources in section 2. Section 3 lays out a demand system for rentals and purchases of a movie on a particular format and provides a simple example via the theory model of the upstream firm's choice of whether or not to use second-degree price discrimination. In section 4 I describe the dataset and the timing of rentals and sales. Section 5 modifies the demand system to incorporate some institutional details and describes the estimation strategy. There are two main sets of parameters to estimate: quality levels of different movies and formats, and parameters of the distribution of consumer tastes. The data include observations from more than 2,000 local markets on 41 major movie releases. Intuitively, identification of the quality parameters comes from differences in overall performance across titles (cross-title variation), while identification of the parameters of the distribution of consumer tastes comes from differences across markets (cross-market variation). I allow both the quality and taste parameters to vary according to format, and I describe the implied quality differences of the DVD format. Finally, section 6 provides the results of the estimation and counterfactual experiments comparing: the use of rental versus sell-through pricing (ie., the presence or lack of second-degree price discrimination), and also the use of current pricing regimes to the 'first-best' pricing available under a less restrictive copyright act. The current version

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of the paper is missing the results of the counterfactuals–they are coming soon!

2   The Home Video Industry and Previous Use of Market Segmentation

In 1999, the $16 billion home video industry accounted for 55% of studios' domestic revenues, compared to 22% generated by theatrical revenues, and 23% from all other forms of media, such as the sales of pay-per-view, cable, and broadcast television rights.[2] Approximately 20,000 home video retailer outlets plus some internet firms such as Netflix purchase movies on VHS or DVD format and rent their inventory to consumers. In addition, consumers may purchase movies on either format from video, non-specialized, or Internet retailers. The market shares of these two distribution channels are detailed in table 1.

The traditional method of distributing motion pictures on videocassette occurs through two channels: rental and purchase. Table 1 outlines market shares of rentals and purchases according to the type of retail outlet where the rental or purchase occurred, including video specialty stores, discount merchandisers such as Walmart, Internet (both sales and Netflix rentals), and others. The table is constructed from weekly data gathered through phone surveys of consumers' purchase and rental habits. Thus, table 1 includes rentals and sales from all possible distribution channels, including sales of both used and new tapes. The data were provided by Alexander and Associates, which has conducted 1,000 weekly phone surveys on video rental and purchase patterns for over 15 years. The tabulations reflect market shares as of the spring of 2002.

The data for the present study will be drawn from the population in the first row, 'Video Specialty retailers.' Although I will make use of the phone survey data in table 1 to weight my estimated market shares, estimation will rely on a dataset of transaction records from roughly 40 percent of the stores in this row. Details on the actual dataset are provided in section 4. As seen in the table, retailers in this category represent nearly 77 and 74 percent of all VHS and DVD *rentals* respectively. However, a greater proportion of *sales* occur through alternative distribution channels, including Internet and non-specialized retail outlets. Video specialty retail stores represent only 23 and 10 percent of VHS and DVD sales. Fortunately, one can weight the sample accordingly on the basis of the phone-survey data.

As discussed in the introduction, video retailers traditionally pay a linear price to the

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[2]VSDA Annual Report, 1999.

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distribution arm of a movie studio for ownership of a pre-recorded videocassette tape of a movie.[3] Price varies little by title, with distributors typically charging a wholesale price between $65 and $70 per tape, regardless of the identity of the movie.[4] After an initial period of rental activity (around six months), the distributor cuts the price from the $65 - $70 range to $10 - $15 wholesale. This two-tiered pricing strategy essentially allows the distributor to price discriminate intertemporally between institutional and individual buyers. The act of reducing price in the second stage is referred to as "sell-through re-pricing." Exceptions to this typical two-tiered pricing pattern are titles priced for "sell-through." In this case, the two-tiered pricing strategy is discarded in favor of an immediate low price to stimulate early sales to end-users.[5] Tables 2 and 3 detail the use of sell-through pricing for the VHS and DVD formats respectively. These figures are compiled from the dataset detailed in the next section, but include all major titles released between January 1998 and December 2001 in the case of VHS, and between January 2000 and December 2001 for DVD. Titles classified as "B" or "A" earned 15-40 million or more than 40 million respectively in theatrical box-office revenue. Table 2 shows the incidence of sell-through pricing for titles released on VHS. Childrens and Family movies are always sell-through priced, while Romance titles are never sell-through priced in the dataset. Science Fiction titles are equally likely to be sell-through priced or rental priced if the title has a large theatrical box-office, but are quite unlikely (13 percent) to be sell-through priced if the theatrical performance was poor. Contrasting to this, table 3 shows the use of sell-through pricing for movies under the DVD format. The titles correspond to many of the same titles in table 2, but covers only the second two years of the data period (2000 - 2001). With the exception of a single B title in the Drama genre, all titles are sell-through priced.

Finally, one might wonder what the growth of the DVD format looks like during the

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[3]The distribution arm of a movie studio is the upstream firm in this context. For the remainder of the paper, I refer to the upstream firm as the distributor.

[4]According to industry sources, the marginal cost of producing, packaging and shipping a pre-recorded videocassette tape is around two dollars.

[5]Prices obtained through interviews with studio executives. Other volume discounts or price breaks through "copy-depth" programs may apply. Such copy-depth programs were most widely used in 2000, and were less common in 1998 and 1999. I do not observe these discounts, and assume that retailers pay the full wholesale price before discounts. In addition to the traditional fixed-fee or linear pricing, revenue-sharing contracts became a widely-used contractual arrangement between retailers and distributors beginning in 1998. These distribution contracts are discussed in detail in Mortimer (2002). For much of the present analysis, I focus on 46 titles with theatrical box office revenues of more than 55 million dollars, and for which revenue-sharing contracts were not available. More detail is provided in the next section which describes the data.

period of analysis, which is 2000 and 2001. Growth rates of DVD rentals and sales and DVD hardware adoption are presented in Table 4. DVD households, which counts households with one or more DVD players and excludes households in which the DVD player is attached to a PC but not used for entertainment, grow from 12 million at the end of 2000 to 24 million at the end of 2001. Quarterly growth rates show faster growth during the fourth quarter of each year due to holiday purchases. The rate of DVD hardware adoption has been extraordinarily fast: as much as 10 times faster than VCR adoption according to some industry sources. Anecdotal evidence suggests that in addition to purchasing the new hardware to augment or replace an existing VCR, consumers have also replaced CD players with DVD machines.

DVD rentals and sales have also shown fast growth. The second and third rows of table 4 show total expenditures on DVD rentals and sales, and rows 4 and 5 show the implied growth rates. Rentals grew at a pace of 90 percent from 1999 to 2000, and grew even faster, at a rate of 146 percent, in 2001. Sales grew 146 percent from 1999 to 2000, and grew at a rate of 66 percent in 2001. Interestingly, the pattern of growth rates of rentals and sales is consistent with an adoption pattern in which consumers with relatively low values of 'taste' for movie quality (ie., consumers more likely to rent than buy) adopt DVD hardware later than consumers with high values of taste for movie quality (ie., consumers more likely to buy than rent). Of course, this is merely suggestive evidence, and does not in any way establish a relationship between observed growth rates and unobservable tastes for movie quality.

3 A Theoretical Model of Firm Behavior

In this section, I describe a model of consumer demand and firm behavior that specifies the conditions under which second-degree price discrimination (i.e., rental pricing) is a more profitable pricing strategy than non-discriminatory linear pricing (ie., sell-through pricing). I also compare these outcomes to the results when firms are able to use third-degree price discrimination by charging different prices to different types of users. The model consists of a demand system for consumers and a supply decision for firms. Consumers consider a single product that is vertically-differentiated according to whether or not the product

is rented or purchased.[6] The supply decision specifies firms' profit functions and solves for the optimal pricing strategy. I consider three possibilities. First, the firm is able to simultaneously charge different prices in the two markets (rental and purchase). This is the first-best strategy for firms, but is not feasible in the U.S. market because of the Copyright Act of 1976. Second, I consider simple linear pricing without price discrimination. Finally, I consider the use of intertemporal price discrimination with a decay in the value of the purchased product over time.

3.1 Consumer Demand

I consider a simple model of consumer demand for two vertically-differentiated products: the rental or purchase of a given movie title on a particular format. For each title, I assume that the upstream firm (in this case, the movie studio) has monopoly ownership of that title. Consumers' utility functions are specified by:

$$u_i = \begin{array}{ll} \nu_i \delta_s - p_s & \text{if purchase} \\ \nu_i \delta_r - p_r & \text{if rent} \\ 0 & \text{otherwise} \end{array} \tag{1}$$

The parameters δ_s and δ_r represent the quality of purchasing and renting respectively; p_s and p_r denote the prices for purchasing and renting the good. The parameter ν_i differs across individuals and represents a consumer's 'taste' for purchasing or renting the movie.[7]

Consumers prefer to purchase when $\nu_i \delta_s - p_s > \nu_i \delta_r - p_r$, and they prefer to rent when $\nu_i \delta_s - p_s < \nu_i \delta_r - p_r$ and $\nu_i \delta_r - p_r > 0$. Assuming that the quality of purchasing is greater than the quality of renting ($\delta_s > \delta_r$), consumers purchase if their value of ν_i is sufficiently high:

$$\nu_i > \frac{p_s - p_r}{\delta_s - \delta_r} \equiv \tilde{\nu}.$$

And consumers rent if their value of ν_i meets the conditions:

$$\nu_i < \frac{p_s - p_r}{\delta_s - \delta_r} \text{ and } \nu_i > \frac{p_r}{\delta_r} \equiv \hat{\nu}.$$

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[6]In the empirical work, I also distinguish between purchases of used and new tapes. Further discussions of this issue appear in the data description and estimation sections.

[7]As is well-documented, we can also re-write this so that the ν_i parameter affects the disutility of price, thus providing for an interpretation that it is differences in income, not differences in 'taste for movie watching' that matters. See Tirole (1995) pp. 96-97.

Consumers with $\nu_i < \hat{\nu}$ consume the outside good. Thus, if N is the number of consumers in the market, demand is given by

$$N(1 - F(\tilde{\nu})) \quad \text{in purchase market}$$
$$N(F(\tilde{\nu}) - F(\hat{\nu})) \quad \text{in rental market.}$$

(2)

3.2 Definition of Profit Functions

The rental and sales markets for VHS and DVD formats of a movie are both characterized by a vertically-separated industry structure, in which retailers and studios are separately owned. Consider an example with a single retailer and a single studio; I specify profit functions for the retailer and studio in the sales market as:

$$\pi_{ret}^s = N(1 - F(\tilde{\nu})) \cdot (p_s - p_w^s), \text{ and}$$

$$\pi_{stud}^s = N(1 - F(\tilde{\nu})) \cdot (p_w^s - c).$$

The parameter c is the production cost for the studio, and p_w^s represents the wholesale price charged to retailers by the upstream studio. If there is perfect competition in the retail sector and no additional costs incurred by the retailer, $p_s = p_w^s$. The presence of any mark-ups or additional costs for the retailer at the point of sale would lead to $p_s = p_w^s + \mu_s$ where μ_s is the retail mark-up.

In the rental market,

$$\pi_{ret}^r = N(F(\tilde{\nu}) - F(\hat{\nu})) \cdot (p_r - p_w^r/\tau), \text{ and}$$

$$\pi_{stud}^r = N(F(\tilde{\nu}) - F(\hat{\nu})) \cdot (p_w^r - c) \cdot (1/\tau).$$

These specifications assume that each videocassette tape or DVD produces τ rentals.[8] If there is perfect competition in the retail sector and no additional costs incurred by the retailer, $p_r = p_w^r/\tau$. Again, the presence of mark-ups or additional costs incurred by the retailer at the point of sale would lead to $p_r = p_w^r/\tau + \mu_r$.[9] Taking both the sales and rental markets, the upstream firm maximizes:

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[8]In later sections of the paper, I distinguish between the VHS and DVD markets, and τ, along with other parameters of the model, is allowed to vary across formats. I also allow τ to differ depending on whether rental pricing or sell-through pricing is used.

[9]Of course, one can always consider more complicated relationships between the inventory decisions of the retailer and the production of rentals. I discuss this issue in Mortimer (2002) and compare robustness tests of alternative views of the τ variable in the context of revenue-sharing programs.

$$\max_{\{p_w^r, p_w^s\}} \pi_{stud} = N(1 - F(\tilde{\nu})) \cdot (p_w^s - c) + N(F(\tilde{\nu}) - F(\hat{\nu})) \cdot (p_w^r/\tau - c/\tau)$$

where $\tilde{\nu} = \tilde{\nu}(p_w^s, p_w^r, \delta_s, \delta_r, \tau)$ and $\hat{\nu} = \hat{\nu}(p_w^r, \delta_r, \tau)$ as before, and $F(\nu)$ is the cumulative distribution function of ν. (I have assumed retailer mark-ups are zero for the purpose of the simple example; mark-ups are estimated when I take the model to data.)

Market Segmentation (Third-degree Price Discrimination)

Under third-degree price discrimination, the upstream firm sets different prices in the 2 markets simultaneously. This should be the 'first-best' solution for the studio (assuming it can always choose $p_w^s = p_w^r$). Note that when retailer mark-ups are zero,

$$\hat{\nu} \equiv \frac{p_w^r/\tau}{\delta_r}, \text{ and } \tilde{\nu} \equiv \frac{p_w^s - p_w^r/\tau}{\delta_s - \delta_r} \tag{3}$$

All rental stores pay p_w^r and all consumers pay p_w^s; rental consumers pay p_w^r/τ for a rental. This strategy is not feasible under current U.S. Copyright law because firms are not allowed to charge different prices for different uses of the product, but it represents a strategy available to (and used by) firms in many other countries.

No Price Discrimination

The second case considers the upstream firm's pricing problem in the absence of price discrimination (sell-through pricing). I denote the single wholesale price as p_w. Note that the cutoffs which affect market shares (again assuming retailer mark-ups are zero) are now:

$$\hat{\nu} \equiv \frac{p_w/\tau}{\delta_r}, \text{ and } \tilde{\nu} \equiv \frac{p_w - p_w/\tau}{\delta_s - \delta_r} \tag{4}$$

The difference between the first case and the second case is that in the first case (equation 3), the relative price of a sale compared to a rental is under the control of the upstream firm (ie., $\tilde{\nu}$ depends on p_w^s and p_w^r). In the second case (equation 4), relative prices for the two products (purchase versus rental) are constrained by τ (ie., $\tilde{\nu}$ depends only on p_w, and $p_w^s/p_w^r = \tau$).

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In the absence of the ability to use market segmentation, upstream firms recognized that it might be possible to discriminate over time. Thus, after *Universal v. Sony*, they essentially introduced a new dimension to the pricing problem so far laid out, adopting a pricing strategy that used a single discrete change in price after 4-6 months of a title's initial release in order to discriminate between low-value and high-value types of consumers. Theoretically, there is no reason to rule out a much more flexible use of the temporal dimension, where firms adjust their prices at many points in time. In practice, and for reasons that I will not attempt to explain here, upstream firms in this industry have instead consistently chosen a single repricing date, effectively using two time periods over which to discriminate. Consequently, I focus on the firms' decisions to either price discriminate over two periods or to not price discriminate at all, and the effects of these decisions on consumers. I compare the outcomes of these strategies to the outcomes of pricing strategies that use market segmentation in the first period (as allowed in other countries).

Intertemporal Discrimination Over Two Time Periods
(Second-degree Price Discrimination)

The third case considers intertemporal price discrimination over two time periods (rental pricing). This has been the predominant method of pricing in the VHS market historically, with the exception of the use of revenue-sharing contracts. Suppose that the value of the good to consumers decays at rate ρ so that the value of purchasing in the later period is $\rho\delta_s$ where $\rho < 1$. Thus ρ is treated as a relative discount factor, applied to the quality of a movie.[10] This is meant to reflect such effects as word-of-mouth and other factors that might influence the quality of owning a movie over time, relative to the standard discount factor.[11]

I make the assumption, consistent with industry facts, that the rental market is fully served in period one.[12] Thus, for the purpose of this example, I make no distinction between

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[10]The parameter ρ differs from the usual discount factor because it does not apply equally to the quality of the movie and the price and cost factors. One could easily incorporate a discount factor for price and cost: the simplifying assumption here is that the standard discount factor is equal to one, while the quality of owning the movie has an additional discount factor which is equal to $\rho < 1$.

[11]A more critical simplifying assumption in the model is that upstream firms do not choose ρ (for example, by engaging in special sales-oriented advertising campaigns or other initiatives). However, it is difficult to identify such effects empirically, and I do not think the 'choice' of ρ is a first-order decision for the upstream firm in this context.

[12]One could extend the model to explicitly incorporate the cost structures and profit maximization problem

a rental in period two and consumption of the outside good. The use of intertemporal price discrimination introduces a third product into consumers' choice sets. Consumers can rent in period 1, wait and purchase in period 2, or they can purchase in period 1, along with video rental stores. Thus, consumers maximize utility over the choices:

$$
u_i = \begin{array}{ll}
\nu_i \delta_s - p_w^r & \text{if purchase in period 1} \\
\nu_i \rho \delta_s - p_w^s & \text{if purchase in period 2} \\
\nu_i \delta_r - p_w^r/\tau & \text{if rent in period 1} \\
0 & \text{otherwise}
\end{array}
\tag{5}
$$

where p_w^r is the price of purchasing a tape in period 1, and p_w^s is the price of purchasing a tape in period 2. The price of a rental (assumed to occur in period 1) is p_w^r/τ. The cutoff points across the distribution of ν are now:

$$
\hat{\nu} \equiv \frac{p_w^r/\tau}{\delta_r}, \tilde{\nu} \equiv \frac{p_w^s - p_w^r/\tau}{\rho \delta_s - \delta_r}, \text{ and } \bar{\nu} \equiv \frac{p_w^r - p_w^s}{\delta_s - \rho \delta_s}
\tag{6}
$$

While the firm now has more control over the relative prices of rentals and sales compared to no price discrimination, ($\tilde{\nu}$ and $\bar{\nu}$ depend on p_w^r and p_w^s rather than a single p_w), they face the reality that the value of the product for purchase in period 2 has decreased (by factor ρ). The use of market segmentation within each period would be strictly preferred, since the firm could then set a first-period price for purchase in addition to the second-period puchase price and the first-period rental price. Case 1 is a corner solution of the two-period market segmentation strategy in which the firm sets prices to induce all consumers to purchase in period one. I leave a proof of the conditions under which the corner solution with market segmentation is optimal for later, and proceed with a comparison of the three (non-nested) cases.

Whether or not the firm will prefer to use second-degree price discrimination, or no price discrimination, under these conditions depends upon 1) the discount rate ρ, 2) the distribution of ν, and 3) the relative quality of renting versus owning. The next section provides results from a simulation of the model for particular parameter vectors to give some intuition for when second-degree price discrimination is preferred to none (i.e., when rental pricing is preferred to sell-through pricing).

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facing retailers. Such a model will lead to the rental market being served in the first period if there is sufficient competition between the retailers, or between video retailers and other distribution channels for a movie such as cable, pay-per-view, etc. The assumption that the rental market is served in period one is supported empirically.

3.2.1 Numerical Example

For the cases outlined above, one can estimate prices, market shares (for the purchase and rental products of a title), firm profits, and consumer surplus if the parameters $(N, \tau, c, \delta_s, \delta_r, \rho)$ and any parameters of the distribution of ν are known (along with retail mark-ups, which we have so far been assuming to be zero). To provide a simple example of the upstream firm's pricing decision, I solve the firm's profit-maximization problem over a range of parameter values and provide a graph showing the values over which rental-pricing or sell-through pricing strategies are optimal. For this example, I assume that ν has a Weibull distribution with parameters (λ, α) and retailer mark-ups are zero (i.e., $\mu_r = \mu_s = 0$). I assume there is a single upstream firm and a single, price-taking retailer. I also assume $N = 1, c = 2, \delta_s = 1.6$, and $\alpha = 2.9$. I solve for the optimal pricing strategy over a range of values for λ and δ_r assuming that the upstream firm effectively cannot use third-degree price discrimination. I consider a few alternative assumptions about the parameters τ and ρ, which are discussed shortly.[13] The values of λ that I consider range from 0.17 to 0.40, implying a mean value of ν of 1.1 to 0.23, respectively for the given value of $\alpha = 2.9$. The values of δ_r that I consider range from 0.23 to 1.1 (equal to 1/7th of the value of owning and 2/3rds of the value of owning, respectively).[14]

Results are shown in figure 1 for three alternative specifications of τ and ρ. The area down and to the left of each line represents the values of λ and δ_r for which the upstream firm prefers rental pricing to sell-through pricing. Starting with the solid line (closest to the lower left-hand corner), I show the results when $\tau = 20$ and $\rho = 0.90$. When the relative quality of renting versus owning is high (so that consumers get a large part of the value of a movie by seeing it one time), rental-pricing is preferred. For a "high enough" δ_r (relative to δ_s), rental-pricing is preferred over a large range of $E(\nu)$. However, as $E(\nu)$ becomes large, rental-pricing is no longer preferred. When the market has many low-value consumers, or when renting is a relatively high-quality good compared to owning, rental-pricing is the firm's most profitable strategy. On the other hand, when the value of owning is a large multiple of the value of renting (perhaps because consumers watch the movie many times), a sell-through strategy is preferred. This accords well with the casual evidence that firms

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[13]In the empirical work, I relax many of these modeling assumptions; for example, I allow for greater variation in τ, and I estimate retailer mark-ups.

[14]I show results for discrete changes in λ (increments of 0.1) and δ_r (it decreases from $\delta_s/1.5$ to $\delta_s/7.0$ in increments of 0.5 in the denominator).

nearly always use sell-through pricing strategies for children's movies, and Blockbuster hits.

The next closest dotted line in figure 1 shows the parameter values for which rental-pricing is preferred when inventories are used differently under the two pricing strategies. Retailers are still assumed to have no mark-ups for this simple example, but I allow for the fact that inventories may be used more intensively when a movie is rental priced. As this is an empirical regularity in the industry, I assume that sell-through priced movies produce 20 rentals from each tape, while rental priced movies produce 30 rentals from each tape.[15] There are two potential effects here: one is that the constraint on the relative price of a rental, compared to the price of a purchase, differs as a function of τ. The other is that the cost of producing a rental is lower. Whether or not different values of τ make rental-pricing or sell-through pricing more attractive is essentially an empirical question. In this example, there is a slightly wider range of parameters over which the firm will choose rental-pricing. Finally, in the outermost dotted line, I show the results when τ differs in the same way as above, but $\rho = 0.95$ rather than 0.90. More patient consumers (a higher ρ) results in rental pricing being preferred over a larger set of values for λ and δ_r: if consumers are more patient, there is not as much to lose by delaying the good introduction of the good to the purchase market.

The point of this exercise has been two-fold. First, providing solutions to the model under these simplifying assumptions is intended to motivate the use of a similar demand model in estimation. Second, the numerical example is intended to motivate and identify the parameters that affect the pricing decisions of the upstream firm. Now I turn to a description of the data, and following that, I describe the estimation methodology.

4   Data

4.1   Description

The data for this study are provided by Rentrak Corporation. Independent retailers, as well as many large retail chains, rely on Rentrak as a central source for the provision of monitoring services for the enforcement of revenue-sharing contracts. Revenue-sharing contracts help to mitigate the understocking and double-marginalization problems that arise

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[15]Empirically, retailers produce around 16 rentals per tape on average for sell-through priced titles, and 24 rentals per tape on average for rental priced titles. rental priced titles are more likely to be rationed in early weeks.

under the two-tiered rental-pricing regime, but they require extensive computer monitoring to be enforced. Previous papers have studied these contracts: Dana and Spier (2002), and Cachon and Lariviere (2002) provide theoretical analysis. Mortimer (2002) provides an empirical study of the welfare effects of these contracts.

Fortunately, however, monitoring through the Rentrak system occurs for all titles, not just those for which revenue-sharing contracts were selected. Over 10,000 retailers used Rentrak between 1998 and 2001, accounting for over half of all retailers in the industry. Blockbuster Video and Hollywood Video comprise about 4,000 of these retailers, and I do not observe their transactions.[16]

In the complete, four-year panel of the data I observe 9,027 retailers, ranging in size from single-store locations to a chain with 1,652 locations. Of these 9,027 retail locations, I am able to match 7,592 stores with local demographic and additional data. These stores represent nearly half of the stores in the industry. For these stores, I observe up to 236 weeks of transactions between January, 1998 and June, 2002. Transactions for VHS tapes are tracked for the entire period that a store is in the database; however, DVD activity is only tracked beginning in January, 2000. Thus, I discard observations for titles released before January 2000 and I focus on tracking the performance of each title on both its VHS and DVD format. Due to entry and exit from the database, I observe only 4,341 stores with complete demographic and phone book data during the years of 2000-2002 when DVD data are collected. For this study, I further eliminate 2,128 stores that did not carry most of the major titles during the period. This eliminates stores that either exited the database at an early date, or entered the database at a late date. This leaves a dataset with 2,213 stores whose rental and sales transactions are recorded from January 2000 to June 2002.

The data may be further described according to the frequency with which I observe each variable. At the store level, I observe location at the county, zip code, and Designated Market Area (DMA) level for each of the 2,213 stores.[17] For each title, I observe the number of titles released in the same month under different contract types, a box-office category, genre (such as Action/Adventure, Children's, etc.), and MPAA rating (such as R, PG-13, etc.). I focus on titles with theatrical box office revenues of at least 55 million in order

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[16]Blockbuster Video does not release their data, and only process some titles through Rentrak's system. Hollywood Video recently settled a lawsuit with Rentrak involving a dispute over data integrity.

[17]Designated Market Areas organize the United States according to the coverage areas of broadcast television.

to ensure sufficient coverage of the sales market. I discard titles released after December, 2001 so that rental and sales activity for each title is tracked for at least 6 months on both formats. For the current set of results, I also limit my attention to titles that are not available on revenue-sharing contracts. Although I do not observe title or studio names, I do observe that many of these titles come from two studios that are fairly large in terms of releases. The title and studio characteristics look quite representative of other titles in the database. In future versions, I hope to incorporate a comparison between alternative pricing regimes in combination with revenue-sharing programs. The final dataset includes the rental and sales performances of 41 titles at 2,213 stores on both VHS and DVD formats.

The Rentrak dataset is an especially rich source of information on firm behavior. However, Rentrak cannot provide information on local competitive conditions facing each store in the database. In order to observe (or at least proxy) for local competitive conditions, I use Yellow Pages listings for all video retail stores in the United States, including Blockbuster and Hollywood Video stores, for 1998 through 2002. From these data, I identify the total number of video retail stores within the same zip code of each observed store in the Rentrak database. In addition, I utilize data from the 2000 US Census on the demographic characteristics of each zip code. Demographic data include the number of people, median income, and marginal distributions of race, education, age, gender, employment, family status, and the level of urbanization in each zip code. These three data sources are merged by zip code. When estimating the model, I define a local market as a zip code area and use the merged data to characterize local market conditions. Clearly, zip code areas are designed to provide convenient local areas for the purposes of delivering mail, rather than as definitions of local markets. However, zip code areas appear to be a reasonable demarcation between markets in this setting: the average zip code area contains approximately 24,000 people and 2.6 video retail stores. Larger areas, such as 4-digit zip code areas or Metropolitan Statistical Areas (MSA's) are also feasible ways of attaching local demographic and business listing information, but seem too large a market for most video store customers.

An additional step for defining markets is to specify the portion of consumers that are active in the market for either the DVD or VHS format. For this, I use data from the Consumer Electronics Manufacturers' Association on quarterly DVD hardware penetration rates. Unfortunately, these penetration rates are only available at a national level. I assume that hardware penetration occurs uniformly across local markets by quarter; there is support

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for this assumption in the Video Software Dealers Association (VSDA) 2002 Annual Report and other industry reports, although market-specific penetration rates would be preferrable. I assume that after a household has purchased a DVD player, they always rent or purchase on the new DVD format, even though they may record and watch previously-purchased VHS movies on the old VCR.

Finally, the market for sales of VHS tapes and DVDs also includes some sales of used tapes from stores' rental inventories. Unfortunately, sales transactions are not recorded separately as used or new. Thus, the best definition I have for distinguishing between new and used products is on the basis of price. I estimate wholesale price as being equal to 60 percent of the suggested retail price. This estimate is also borne out by industry interviews. Thus, I classify a sale as 'used' if the average weekly price of sales for a given title at a particular store is below the wholesale price of a new tape. This classification identifies approximately 80-85 percent of all sales at my observed video specialty stores as used. I checked these estimates with professionals in the industry and with more detailed tabulations of the phone-survey data in Table 1. For purposes of weighting the sales and rental observations, I assume that all sales of used tapes occur through video specialty stores (and not, for example, through mass-merchandisers like Walmart).

4.2 Timing of Rentals and Sales

Identification rests on a demand model in which the timing of rentals and sales depend on whether or not a title is subject to intertemporal price discrimination. Under sell-through pricing, rentals and sales should both occur simultaneously (in "period 1.") Under rental-pricing, rentals should occur in period 1. A few, very high-value consumers may purchase the title in period 1, and then most sales should occur in period 2 (depending on price, the discount rate and the parameters of the distribution of consumer tastes.)

Table 5 provides summary statistics from the data on both the quantity and timing of rentals and sales on both formats. For the 41 titles used in the analysis, I computed weekly totals of rentals and sales for each title based on the first week it appeared at a store. The top half of the table refers to those titles with a rental priced VHS release. The bottom half of the table refers to those titles with a sell-through priced VHS release. All titles (including those with a rental priced VHS format) are sell-through priced on the DVD format. Of the 41 titles, 29 are sell-through priced (in the lower half) while 12 are rental priced (in the

17

top half). The left half of the table reports total rentals and sales, and cumulative monthly rental and sales activity for the VHS format, while DVD results are reported in the right half of the table.

I first discuss the timing of rentals and sales, and then discuss the totals and weighted totals for the four different classifications of titles: rental priced VHS titles in VHS and DVD formats, and sell-through priced VHS titles in VHS and DVD formats. Columns 1 and 4 provide information on the timing of rentals over months for VHS and DVD. Across all four categories, approximately two-thirds of all rentals occur during the first eight weeks (2 months). At least 85 percent of all rentals occur in the first 21 weeks (5 months).

Columns 2 and 5 examine used sales. Relatively few sales of used tapes or DVDs occur during the first two months when the rental market is most active; however, by week 21, roughly half of all used sales have occurred. I do not distinguish between the timing of used sales for three reasons. First, unlike rentals and new sales, the sales of used tapes are not as clearly delineated by timing. Second, the choice of whether or not to use intertemporal price discrimination, and the effects of price discrimination on producer and consumer surplus are not likely to be affected by the distinction between early and late used sales. Finally, in table 6, there is little difference in the price of used tapes over time; in fact, the average price of a used tape is actually higher in later months than in early months for DVDs that were rental priced on VHS. The timing of rentals and used sales are similar across the four quadrants of table 5.

Finally, columns 3 and 6 examine the timing of the sales of new tapes or DVDs. For rental priced VHS titles, relatively few sales of new tapes (less than 15 percent) occur during the first 21 weeks (five months). In contrast, roughly three-fourths of all new sales take place in the first five months for sell-through priced VHS titles, and this figure is nearly 85 percent for all DVD titles. I classify sales occurring during the first 5 months as "period 1 sales." It is straightforward to test the robustness of my estimates to perturbations in this cut-off point. There were two reasons that I chose 5 months as the cut-off point between the two periods of the model. First, this corresponds to the timing of the sell-through re-pricing done by the studio for rental priced VHS titles. Second, the data seem to conform best to this definition when one examines table 5.

Strictly speaking, the theory model described earlier predicts that 100 percent of new sales should occur during period 1 for DVDs and for sell-through priced VHS. The fact that

15 to 25 percent of the sales actually occur in my period 2 could reflect either consumers who wanted to purchase in period 1 but found the title out of stock, or they could just reflect the revealed preferences of consumers with idiosyncratic timing preferences. For example, a consumer could be purchasing the tape for a friend's birthday which occurs in week 25. In estimation, I assume that consumers are just as happy purchasing these titles in period 2, and I treat the quality of the sale in these cases as being no different from the quality of earlier sales of the same titles. Of course, there is no way to test which of the two types of assumptions is correct, and I've chosen one of two extreme assumptions here. However, the assumption is somewhat supported by examining prices over time.

Prices of rentals and sales by month are shown in Table 6, which is also organized according to the pricing pattern used for a film's VHS release. Rentals of DVDs are slightly more expensive; there are no significant differences in the price of a rental according to whether or not a film was rental priced. This is somewhat surprising: the model predicts that lower costs of inventory should yield lower rental prices to consumers. It seems the old model of 99-cent children's rentals is no longer found in the data (and for that matter, one might expect 99-cent DVD rentals). I say more about this in the discussion of retailer mark-ups later in the paper. Prices of rentals do not change after month 5, because I aggregate rental transactions that occur after week 21 and report the average price. Prices of used sales are also slightly higher for DVDs, and there are no significant differences between prices of used tapes based on whether or not rental pricing was used for a film's VHS release. Prices of new sales in period 1 differ significantly for rental priced VHS tapes. Average prices during the first five months (before sell-through re-pricing occurs) range from $89 to $100. In contrast, prices of new sales in period 2 (months 6 and higher) average between $18 and $27. For sell-through priced VHSs and all DVDs, prices of new sales in the second period are very similar to prices of new sales in the first period, although there is some reduction in price over time.

Table 7 shows total activity levels in the data, as well as weighted totals. Most of the sales that occur in this population of stores are sales of used tapes. The weights applied to new sales are much larger, as I discuss in the estimation section. The ratio of total weighted sales to total weighted rentals across the four quadrants shows a higher overall level of weighted sales for DVDs compared to VHSs: 29.9 and 34.5 percent of rentals for DVDs versus 13.2 and 7.5 percent of rentals for the same titles on VHS format. Note that by

comparing the different titles on the DVD format, one should get a sense of the importance of the endogeneity of the sell-through pricing decision. DVDs are priced the same for all titles, so the extent to which sell-through priced titles sell better on DVD than rental priced titles should be due to unobservable characteristics of the titles that make them relatively more desirable to own. This difference in the ratio fo sales to rentals for these sets of titles is 4.6 percent for DVDs (34.5 versus 29.9 percent). Overall levels of DVD activity (including rentals) are higher for sell-through priced titles, but overall levels of VHS activity are higher for rental priced titles.

Titles sell less often on the VHS format. This presumably reflects a relatively higher quality attached to owning DVDs compared to VHS tapes, perhaps because of the increased durability or flexibility for playing the DVDs on laptops, etc. It could also reflect differences in taste for quality across the population of consumers adopting DVD versus VHS. The difference between rental priced titles and sell-through priced titles on the VHS format reflects both unobservable differences in the desirability of owning that lead to a sell-through or rental-pricing decision, as well as the effect of delaying sales of the rental priced titles. The difference here is quite large: sales total 13.2 percent of rentals for sell-through priced titles, compared to 7.5 percent of rentals for rental priced titles. The difference is due to both lower levels of rentals as well as higher levels of sales.

5 Estimation and Identification

The model of demand that is used in estimation is similar to the theory model introduced in section 3, except that I now include an additional product–purchase of a used tape–which has quality level $\delta_u \in (\delta_r, \delta_{s2})$ where δ_{s2} takes the value δ_s if the title is sell-through priced, and takes the value $\rho\delta_s$ if the title is rental priced. In other words, I assume that any used tape has lower quality than any new tape, but higher quality than a rental (for a particular title). I adopt the simple two-period model from section 3 for two reasons. First, I hope that the patterns of rentals and sales in table 5 are convincing that a two-period model is a good first-order approximation to the timing of rentals and sales in this industry. Second, the nature of pricing in this market has always been one in which products are either introduced immediately at one low price, or products are introduced at a high price and are subsequently re-priced once. Thus, the model is very much driven by the institutional details of the industry.

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Empirically, a market is defined to be a zipcode-title-format triple. A market in this context includes three (or four) products: the rental of a title, or the purchase of a new or used tape, on either the VHS or DVD format.[18] Thus, conditional on which hardware they own, consumers decide whether to purchase or rent a given title in their local market. I consider two time periods: before and after sell-through re-pricing, where re-pricing only occurs for rental priced titles on the VHS format, and is assumed to occur after five months.

Demand for rentals and purchases are derived based on the consumer utility functions in equation 5 in section 3, where a consumer's individual taste parameter (ν) modifies the quality parameter for renting or purchasing a given movie (δ). I specify a Weibull distribution for consumer tastes ν, with parameters $\lambda \equiv \exp(X_m'\beta)$ and α, where X_m are observable market characteristics. The probability density function is given by $f(\nu) = \lambda\alpha\nu^{(\alpha-1)}\exp(-\lambda\nu^\alpha)$; the cumulative density function is given by $F(\nu) = 1 - \exp(-\lambda\nu^\alpha)$. The predicted demand levels are calculated based on the distributional assumption on ν; thus, sales (or rentals) as a function of the model's parameters are:

$$
\begin{aligned}
q_{s,m,j} =\ & N \cdot \exp\left(-\exp(X_m\beta)\left(\tfrac{p_{s,m,j}-p_{u,m,j}}{\delta_{s,j}-\delta_{u,j}}\right)^\alpha\right) \\
q_{u,m,j} =\ & N \cdot \left(-\exp\left(-\exp(X_m\beta)\left(\tfrac{p_{s,m,j}-p_{u,m,j}}{\delta_{s,j}-\delta_{u,j}}\right)^\alpha\right) + \exp\left(-\exp(X_m\beta)\left(\tfrac{p_{u,m,j}-p_{r,m,j}}{\delta_{u,j}-\delta_{r,j}}\right)^\alpha\right)\right) \\
q_{r,m,j} =\ & N \cdot \left(-\exp\left(-\exp(X_m\beta)\left(\tfrac{p_{u,m,j}-p_{r,m,j}}{\delta_{u,j}-\delta_{r,j}}\right)^\alpha\right) + \exp\left(-\exp(X_m\beta)\left(\tfrac{p_{r,m,j}}{\delta_{r,j}}\right)^\alpha\right)\right) \\
q_{0,m,j} =\ & N \cdot \left(1 - \exp\left(-\exp(X_m\beta)\left(\tfrac{p_{r,m,j}}{\delta_{r,j}}\right)^\alpha\right)\right)
\end{aligned}
\tag{7}
$$

where $\delta_{r,j}, \delta_{u,j}$ and $\delta_{s,j}$ represent the quality levels of the appropriate format for title j (ie., $\delta_{r,j}$ takes the value $\delta_{r,j}^v$ and $\delta_{r,j}^d$ for VHS and DVD formats respectively.) Note that quality parameters are defined in such a way that they are assumed to not vary by market. The quality of a movie is thus assumed to be constant across the nation, although local tastes

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[18]An alternative market definition might include rentals and sales of other titles released during some defined window of time. The inclusion of competing titles, although a potentially attractive extension of the model, also has potentially complicated interactions with the pricing decisions of the upstream firm. The advantage of such a market definition is that it allows for a rental of *Saving Private Ryan* to compete with a purchase of *Thin Red Line*, for example. The less straightforward issue is how the pricing decisions might potentially interact. If 20th Century Fox prices *Thin Red Line* at sell-through, is Dreamworks more or less likely to price *Saving Private Ryan* at sell-through, or rental pricing? The answer depends on the assumptions about the nature of competition at the upstream level. The present market definition, which ignores competition between titles, is consistent with the assumption that studios maximize video revenues from a movie as a monopolistic provider of that title, independently of the releases and pricing decisions of competing studios' movies. Having made this assumption, I drop title subscripts throughout the paper for ease of notation. For a discussion of the use of zipcodes to define geographic markets in this industry see Mortimer (2002).

for movies may differ. I will say more about this issue later in the section.

Prices may vary by market ($p_{r,m,j}$, etc.) and also apply separately to VHS and DVD formats (thus, they have a suppressed v or d superscript similar to the quality variables). Local demographic shifters (X_m) include median income, the percent of the area that is suburban, store size, the percent of families who are married with kids, and an interaction of this with a dummy for whether or not a title is a kid's movie. Estimation is done completely separately for the two formats, although in order for the quality levels of DVD and VHS to be comparable, there is a normalization in the distribution of ν–I do not include a separate constant term for the two formats. However, once X_m has been de-meaned, β is allowed to vary freely across the two formats. The definition of market size, N is discussed at length later in this section.

Most markets rent and sell used tapes for the 41 titles in the analysis. However, many markets have zero market share for new sales.[19] When I observe a zero market share for new sales, I assume the local price is equal to the suggested retail price. Rental priced VHS titles are assigned the original suggested retail price during the first 5 months (21 weeks) before re-pricing, and they are assigned the re-priced SRP in months 6 and later.

I assume that the quality of a new purchase does not change from period 1 to period 2 for DVDs and sell-through priced VHS tapes. However, if a title is rental priced on the VHS format, the sales share is further divided between sales in the first period and sales in the second period. In this case, new sales are:

$$
\begin{aligned}
q_{s1,m,j} =& \ N \cdot \exp\left(-\exp(X_m\beta)\left(\frac{p_{w,m,j}-p_{s,m,j}}{(1-\rho_j)\delta_{s,j}}\right)^\alpha\right) \\
q_{s2,m,j} =& \ N \cdot \left(-\exp\left(-\exp(X_m\beta)\left(\frac{p_{w,m,j}-p_{s,m,j}}{(1-\rho_j)\delta_{s,j}}\right)^\alpha\right) + \exp\left(-\exp(X_m\beta)\left(\frac{p_{s,m,j}-p_{u,m,j}}{\rho_j\delta_{s,j}-\delta_{u,j}}\right)^\alpha\right)\right)
\end{aligned}
\tag{8}
$$

where $p_{w,m,j}$ is the price of a sale in the first period. The number of consumers in a market is given by N, which takes on a value appropriate for either the VHS or DVD market, and also varies across rentals and sales for the population of stores in the Rentrak database. I start with the distinction by format. I assume that once a consumer has upgraded to DVD hardware, they choose to purchase and rent new titles on the DVD format (even though they may continue to record and play older tapes on their VCR machine). I denote $N_{m,q}^{VHS}$

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[19]An additional motivation for selecting this set of titles (aside from the simplification of ignoring revenue-sharing contracts for now) is that there is broad coverage of the titles across many markets. This is especially important for shares of new sales, which are under-represented in my dataset.

and $N_{m,q}^{DVD}$ as the number of consumers in market m and quarter q that rent and purchase movies on VHS and DVD formats respectively. The estimates of $N_{m,q}^{VHS}$ and $N_{m,q}^{DVD}$ in each market are:

$$
\begin{aligned}
N_{m,q}^{VHS} &= [0.90 \cdot POP \cdot (1 - DVD_q)]/STORES_{m,y} \\
N_{m,q}^{DVD} &= [POP \cdot DVD_q]/STORES_{m,y}
\end{aligned}
\tag{9}
$$

where 0.90 is the national penetration of VCRs, assumed to be constant across markets, the variable POP is the population in the zipcode from the 2000 U.S. Census, and the variable DVD_q is the national penetration rate of DVD hardware, which is also assumed to be constant over markets.[20] The variable $STORES_{m,y}$ is the number of video specialty stores listed in the phonebook for that zipcode in a particular year. Typically, I observe roughly 1 of 3 stores in each zipcode neighborhood. Unfortunately, I do not observe rentals and sales at other stores. Dividing N by the number of stores in the market assumes that the unobserved stores have the same characteristics and sales as the observed location, and that phonebook listings represent the total population of video specialty stores.[21]

The second distinction about the market size relates to the fact that I only observe rental and sales transactions from video specialty stores, and not from discount merchandisers or Internet firms. Thus, I need to weight the observed rentals and sales according to the market share of the stores in my database. For this, I use the phone-survey data described in table 1. I assume that purchases from discount merchandisers and Internet firms, etc, occur with equal probability across zipcode areas, and that used tapes are only sold by video specialty stores. The phone-survey data include both used and new sales. Thus, the weight in table 1 gives the weight to be applied for all sales (used plus new). In order to get the correct weight for new sales, I calculate the total number of weighted sales, subtract used sales, and calculate the appropriate weight for new sales. I do this for each store-title pair on each format, using format-specific weights from table 1. Now I can write down the relevant

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[20]In each quarter of the years 2000-2001 I observe total DVD hardware penetration, and I match up titles to these penetration figures based on the quarter in which a title was released. Although I assume that hardware adoption rates are uncorrelated with demographics, the two markets are treated separately, so that the parameters of the distribution of ν (taste for software) may differ across the two formats. The figure for VCR penetration (0.90) is from the VSDA 2002 Annual Report.

[21]Alternatively, one could estimate $S(LOCAL_{m,y})$ where $S(LOCAL_{m,y}) = \gamma_1 STORES_{m,y} + \gamma_2 BB_{m,y} + \gamma_3 HV_{m,y} + \epsilon_{m,y}$, for example, where BB and HV indicate how many of a store's competitors are Blockbuster Video or Hollywood Video stores. Identification of these parameters relies on cross-market variation in observable competitive conditions, as opposed to variation in local demographics or title characteristics which identify β.

market size for each store-format-product as:

$$
\begin{aligned}
N_{r,m,q}^{VHS} &= 0.768 \cdot N_{m,q}^{VHS} \\
N_{u,m,q}^{VHS} &= N_{m,q}^{VHS} \\
N_{s,m,q}^{VHS} &= W_{VHS} \cdot N_{m,q}^{VHS} \\
N_{r,m,q}^{DVD} &= 0.738 \cdot N_{m,q}^{DVD} \\
N_{u,m,q}^{DVD} &= N_{m,q}^{DVD} \\
N_{s,m,q}^{DVD} &= W_{DVD} \cdot N_{m,q}^{DVD}
\end{aligned}
\tag{10}
$$

where W_{VHS} and W_{DVD} are vectors of new sales weights for each store-title pair on VHS and DVD formats respectively. This definition of market size effectively weights the sample of stores appropriately to reflect the national market for the upstream firm. It would be wonderful to have data on new sales from other outlets, such as mass-merchandisers. Unfortunately, I do not observe title identity, so collecting and matching such data is difficult. The number of new sales is smaller than I would like—although it is worth keeping in mind that I do observe between 200 and 600 sales of each title on average on the VHS format, and between 800 and 1,200 new sales for each title on the DVD format in my population of stores.

Now that I have specified a distribution for ν and the relevant market size parameters given by N, we can rewrite equation 7 in terms of the quality parameters. This produces local estimates of movie quality which are of the form:

$$
\delta_{r,m,j} = p_{r,m,j}[-\ln(1 - s_{0,m,j}) \cdot \exp(-X_m\beta)]^{-(1/\alpha)}
\tag{11}
$$

for the example of the quality of a rental; similar solutions are available for the quality of used and new purchases ($\delta_{u,m,j}$ and $\delta_{s,m,j}$). Once again, the quality parameters take values of $\delta_{r,m,j}, \delta_{u,m,j}$ and $\delta_{s,m,j}$ that are format-specific (VHS or DVD). Local market shares are denoted by $s_{0,m,j}$, etc., and are defined as $\frac{q_{0,m,j}}{N}$ using the relevant value of N according to equation 10. The quality parameters for rental priced VHS titles can be solved similarly to incorporate period 1 and period 2 sales.

A product is a title-use-format combination. Each product has a unique, true quality level, which is assumed to be the same across markets. There are many local markets in which I observe a product, and identification of product quality occurs through the use of product dummies. Thus, product quality is essentially estimated off of product-level fixed

effects, not product characteristics. The use of fixed effects here is strictly more general, and is possible because I have so many local markets. The drawback is that one needs to know a product's fixed effect in order to make predictions about new products. I can address this drawback by running a regression of estimated product qualities on observable product characteristics, and will incorporate this in the next version of the paper.

For the rental use of title j on a particular format, I denote the true quality level as $\delta_{r,j}$ (and similarly, for other products). I define differences between a product's true quality level and local estimates of quality given by equation 11 according to:

$$\delta_{r,m,j} = \delta_{r,j} + \xi_{r,m,j}. \tag{12}$$

Thus, local estimates of quality are measured with error (compared to the quality picked up by the product-level dummy). One might wonder what exactly is in the error term $\xi_{r,m,j}$. One interpretation is that $\xi_{r,m,j}$ is misspecification of local tastes, either due to unobservable factors that affect local taste, or due to an incorrect distributional assumption for ν. In the case in which there were no such misspecification, each local estimate of the quality of renting title j would yield $\delta_{r,j}$ exactly. Another interpretation is that $\xi_{r,j,m}$ is in fact picking up something about the local market which actually makes the movie higher quality in that area. To some extent, whether the act of watching a Western on vacation in Montana makes the movie higher quality to me, or merely increases my taste for that movie, is not really something one can hope to separately identify in any dataset. Here, the assumption is that deviations in local quality estimates are simply misspecifications of the local taste for a movie, and do not reflect changes in actual movie quality.

I make the further assumption that $\xi_{r,m,j}$ is orthogonal to both X_m and the product dummies that identify the δ parameters. In other words, for the 'big' movies considered here (each one made more than $55 million theatrically), I assume that neither the upstream nor the downstream firm is taking actions to affect the quality of a movie based on local tastes. Some necessary (but not sufficient) conditions under which this could be expected to hold are: 1) upstream promotions of large movies are national in scope, and do not target specific markets, 2) downstream promotions at the local level do not target specific movies. The assumption fails if firms engage in some activity in order to affect quality of a movie in a local market (ie., providing coupons for a free extra night on a rental of 'Shrek' at the local kids' soccer match, in markets with a high density of kids).

If this assumption holds, one can use equation 12 to form moment conditions:

$$E(Z'\xi_{r,m,j}) = 0 \tag{13}$$

where Z includes the set of product dummies and X_m. The parameters to be estimated are: $\theta \equiv (\delta_r, \delta_u, \delta_s, \beta, \alpha, \rho)$. The parameters $\delta_r, \delta_u, \delta_s$, and ρ are all vectors of length J (the number of titles).

Estimation proceeds using generalized method of moments, choosing θ to minimize

$$\hat{\theta} = \operatorname{argmin} \left(\sum_i \psi(\theta, Z_i) \right)' \ A \ \left(\sum_i \psi(\theta, Z_i) \right).$$

where $\psi(\theta, Z_i)$ is the set of moment conditions and A is a weight matrix chosen to minimize variance according to Hansen (1982).

Just to reiterate, the parameters of the distribution of consumer tastes are functions of local demographics, while the quality parameters are functions of product dummies. At a fundamental level, separately identifying these two sets of parameters (quality and consumer tastes) relies on an assumption that the quality parameters shift across product dummies, but taste parameters (β's) shift across local market characteristics (X's). That leaves only the shape parameter, α, to be identified. Econometrically, the system is overidentified: there are $3kt + k$ parameters to estimate (where kt is the number of titles and k is the dimension of X), but we have $3(kt + k)$ moment conditions. Economically, I believe the shape of the distribution, α, is identified from relative differences in market shares across the types of use of the titles (ie., the relative size of rentals vs. sales in different markets). There is some power in the fact that sequentially higher-quality products are related to each other for the same title, and I believe this helps to identify the shape parameter.

So far, I've discussed the estimation methodology for the parameters $(\delta_r, \delta_s, \beta, \alpha, \rho)$. Note that ρ is the discount rate applied to movie quality, and reflects the degree to which the quality of purchase decreases when consumers wait until period 2 to buy. For titles which are rental priced, ρ is identified as the ratio of the estimated quality parameters of period 2 VHS sales and period 1 VHS sales (ie., δ_{s2}/δ_{s1}). One might be interested in whether or not the same ρ applies to the title's DVD format, and whether or not the same average value of ρ would also apply to titles that were sell-through priced on the VHS format. Naturally, the choice of which titles are sold at a sell-through price versus a rental

price on VHS is endogenously determined by the upstream firm. If the decision is made on the basis of different ρ's for different movies, we cannot identify ρ for titles that were sell-through priced on VHS. However, if the decision is made on the basis of something which is not correlated with ρ (for example, possibly the ratio of δ_r/δ_s), or if ρ is the same across all titles, then one can apply the estimate of the average ρ to sell-through priced titles for the purposes of considering alternative policy outcomes. For the purposes of examining counterfactual outcomes, I assume that ρ is the same for a title's VHS and DVD formats. For titles that are sell-through priced on VHS, I apply the average ρ from rental priced titles of the same genre. (For children's movies, which are always sell-through priced, I use the average ρ of rental priced, PG-13 rated comedies.)

The parameters τ and μ are essentially backed-out from the data directly. The τ parameter is computed from the ratio of rentals to inventory; I allow it to vary by format, genre and pricing type (rental or sell-through pricing) in order to capture the different conditions facing retailers under these different regimes. The μ parameter is estimated as the difference between the observed retail price, and the observed variable cost of the rental, which is given by the wholesale price of a tape divided by the number of rentals per tape for that store-title pair. The wholesale price assumes a 40 percent discount off the observed suggested retail price of each videocassette tape or DVD.[22] The retailer mark-up on sales of used tapes is assumed to be equal to the price, with no proceeds going to the upstream firm.

6   Estimation Results and Welfare Analysis

6.1   Estimation Results

Table 8 provides estimates of the parameters of the model under the restriction that increases in quality from rental to used purchases, and from used to new purchases, are assumed to be the same for all titles (although different for each step up in quality). Parameters of the full model described in the paper will be reported very soon; they are currently being estimated. The estimated parameter values for the distribution of con-

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[22]The wholesale discount figure was obtained through interviews with studio executives and video retail owners. Other discounts (such as volume discounts, bundling discounts, or other 'copy-depth' programs may also apply. I assume that retailers pay the usual wholesale price when reselling tapes, but get a 20 percent discount on rental inventories. These figures were derived from consultations with industry executives; the results are robust to reasonable alternative assumptions on these costs (such as the removal or extension of the additional 20 percent discount.)

sumer tastes indicates that larger stores are located in neighborhoods with higher taste for movie quality. ($E(\nu|x,\theta)$ is decreasing in X.) Median income is associated with higher taste for quality on the DVD format, but does not affect taste for the VHS format. The percentage of the market that is suburban is negatively correlated with local taste for quality, while the estimated parameter value for the interaction of a dummy for kid's movies and the percentage of the market that is married with kids indicates that families have higher tastes for these movies.

The quality parameters indicate that DVD is not of higher quality than VHS. In order for the quality parameters to be comparable across the two formats, one must normalize the mean taste parameters to be the same for both markets; this is why I do not include separate constant terms in the two distributions for ν. (The X variables are defined to have mean zero for each format.) However, I have allowed α to vary across the two formats.[23] The estimates of α and the mean of the distribution of ν for each format differ only slightly from each other. The estimated relative quality of a rental compared to a purchase is only slightly lower for DVDs than for VHSs, but the difference is not significant.

The ρ parameter is estimated as the ratio of the quality of a purchase in the second period and the quality of a purchase in the first period for rental priced VHS titles, and is estimated to be 0.71. The τ parameter indicates that VHS inventory is used more intensively for titles that are rental priced, producing 23.7 rentals per tape compared to 16.9 rentals per tape for sell-through priced titles. DVDs show almost no difference in the rental technology across the two sets of titles, producing 16.1 and 15.7 rentals respectively. Retail mark-ups are higher for the sell-through priced VHS titles and for DVDs: around $2 compared to $-0.04 for rental priced titles on the VHS format, and around $1 for both sets of titles on the DVD format. Sales mark-ups are very high during the first period for rental priced VHS (with an average mark-up of $44), but are around $4 after re-pricing. Mark-ups in the first period for sell-through priced VHS and titles on the DVD format range from $8 - $10.

6.2 Counterfactual Experiments and Welfare Analysis (coming soon)

I am interested in two types of welfare analyses. First, I am interested in the question of whether or not the DVD pricing strategy, which uses no price discrimination, is likely to

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[23]The results are similar when α is normalized to one for both formats (ie., the distribution of consumer tastes in each market has an exponential distribution), although this specification provides a worse fit to the data.

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continue to be the profit-maximizing pricing regime as hardware adoption evolves. In order to answer this question, I use the estimated parameters in table 8 to predict current prices, market shares, variable profits for studios and retailers, and consumer surplus. I then recalculate prices, market shares, variable profits and consumer surplus given the DVD quality parameters, but using the distribution of consumer tastes for quality which was estimated off of VHS data. The exercise supposes that late adopters of DVD hardware will have the same taste for quality that they currently have as VHS users (although I keep the same DVD quality parameters). The point of this exercise, when completed, is to estimate the effects for firms and consumers of price discrimination in the context of the evolution of a new technology. Another approach to check is whether or not significant differences exist when allowing the parameters of the taste distribution to vary 1) over time (especially for the DVD format), and 2) across the two groups of titles based on the VHS pricing strategy (to allow for more flexibility in the endogeneity of the rental-pricing decision).

There are at least two explanations for the current pricing of titles on the DVD format. First, the DVD format may represent a permanent shift in the nature of the 'packaged good' movie product. If the ratio of purchasing to renting quality is much larger for the DVD format, changes in the distribution of consumer tastes are unlikely to affect the optimal pricing strategy. The change in pricing should lead to a decline of the rental industry and a very different form of distribution for this segment of the motion picture industry. The second explanation is that the current pricing strategy of DVDs functions as an introductory pricing mechanism. In this case, high-value consumers, and not the relative difference in purchasing and renting qualities, drive the pricing decision. Thus, changes in the distribution of consumer tastes that results from hardware evolution should lead to a DVD pricing strategy that mimics the strategy used for VHS and preserves the heavy reliance upon a rental market.

Tables 9 and 10 give actual and estimated market shares for VHS and DVD formats respectively, according to whether or not a title's VHS release was rental or sell-through priced. I use actual prices in the construction of market shares under the estimated model parameters. The first column lists actual prices, market shares, and variable profits for upstream and downstream firms. The reported profits are the total variable profits for a title in a market, assuming that mark-ups and prices in the unobserved stores in the market are the same as the mark-ups and prices I do observe. Actual market shares are around 11

to 13 percent for rentals of titles on VHS, and 7 to 8 percent for rentals of titles on DVD. The model is having a difficult time matching the small market shares in the sales market, which are often around 1 percent: for both formats, I overpredict market shares. Profits are predicted quite well for studios, but the overestimate of the market share of rentals leads me to overestimate retailer profits.

The second type of welfare analysis that I am interested in is the effect of the copyright law on producer and consumer surplus. For this question, I compare current outcomes to predicted outcomes under third-degree price discrimination, or market segmentation. Under this comparison, I allow the upstream firm to set two prices in the first period: one for institutional buyers, and one for individual buyers. I calculate producer and consumer surplus under this scenario.

7   Conclusion

Although the current version of the paper is clearly in a very preliminary form, answers to the research questions are in theory quite straightforward. There are two potential sources of difference between the VHS and DVD formats of the same movie. These are: the difference in the relative quality levels of purchasing and renting on the two formats, and differences in the distribution of consumer tastes across the two groups of DVD hardware adoption types.[24] With respect to the first question of whether or not intertemporal price discrimination is optimal for the firm–the answer depends upon which effect dominates. If the relative quality of purchasing compared to renting changes dramatically on the DVD format, one will expect that the use of intertemporal price discrimination will not be optimal for the upstream firm. If differences in consumer taste across early and late adopters is the driving force, one expects that intertemporal price discrimination will be optimal when 'enough' late adopters convert. The initial estimates seem to indicate that the two formats are not significantly different from each other, although I have not yet examined how these differences affect the counterfactual experiments.

The second issue addressed by the paper is to quantify the welfare effects of the U.S. Copyright Act on these types of products, which is more restrictive than the copyright

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[24]It could also be differences in ρ across the two formats. I have not been able to find different sources of data that might separately identify ρ from parameters of the distribution of ν in the case of sell-through priced titles. Future versions of the paper will provide greater detail on how ρ varies across rental priced titles.)

laws of most countries in terms of how much control a copyright holder can impose on the use of a copyrighted good. As seen in the theory section, firms are always worse off when they cannot charge different prices for different classes of use of a copyrighted good. On the other hand, consumers may be better or worse off, depending upon the pricing regime chosen by the upstream firm in the absence of market segmentation. Allowing for market segmentation by giving additional control to a copyright holder may (or may not) increase both consumer and producer surplus. The outcome is essentially an empirical question.

An important extension of this paper is to allow for rental pricing to be used in conjunction with revenue-sharing contracts. The use of such contracts is wide-spread and potentially important for understanding the welfare effects of intertemporal price discrimination. I hope that by providing initial results in a simpler setting, one has a good starting point for this extension. If intertemporal price discrimination can be profitable in the absence of revenue-sharing, then revenue-sharing will only make this comparison more attractive. Furthermore, by reducing some of the inefficiencies of intertemporal price discrimination, revenue-sharing may help to mitigate any welfare losses of the restrictions of copyright law.

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Figure 1: Optimal Pricing Strategies for Simulated Parameter Values
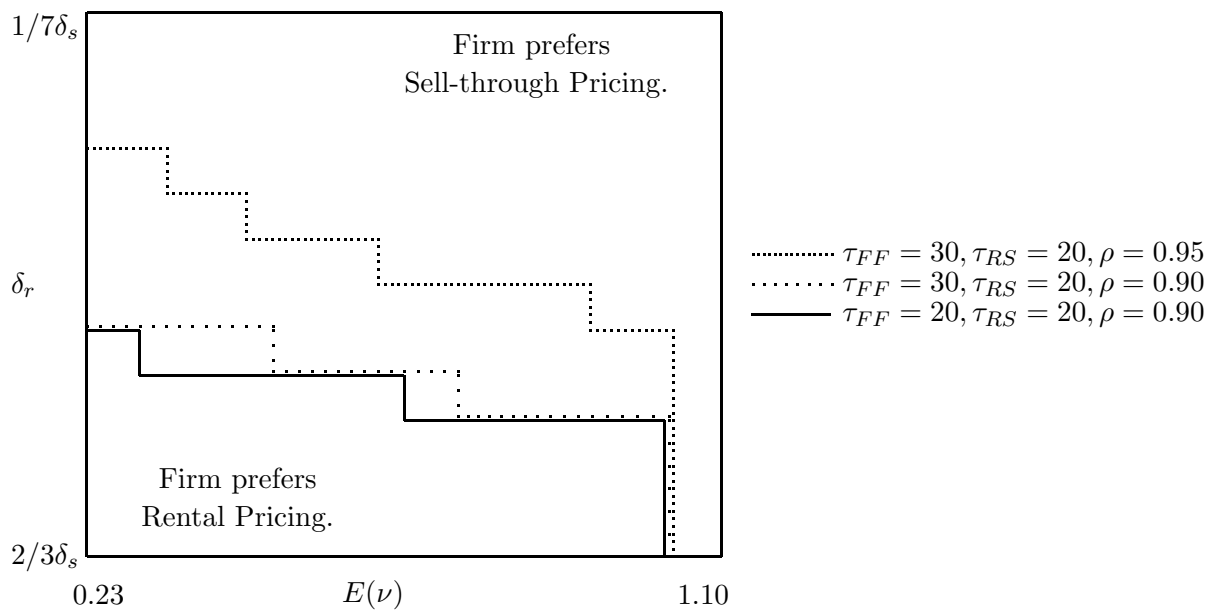
Table 1: Market Shares of Alternative Distribution Channels: Rentals and Sales*

Retail Outlet	VHS Rental	VHS Sales	DVD Rental	DVD Sales
Video Specialty	76.8%	22.9%	73.8%	10.0% (1)
Other brick&mortar/ grocery stores, etc.	23.2	10.7	17.1	30.0 (2)
Internet (Netflix, etc.)	0	1.9	9.1	10.0
Discount merchandiser (ie., Walmart, etc)	0	55.1	0	40.0 (3)
Other (direct mail, etc)	0	9.4	0	10.0

*Data Source: Alexander and Associates. Sales tabulations reflect activity for the second quarter of 2002; rental tabulations reflect activity for May 2002.
(1) Includes Blockbuster at 7 percent (mostly pre-viewed DVDs) and an allowance for other video specialty stores.
(2) Includes Best Buy at 20 percent, Circuit City at 5 percent, and an allowance for others at 5 percent.
(3) Includes Walmart at 29 percent, Target at 8 percent, and an allowance for others at 3 percent.

Table 2: All A and B Titles Released on VHS, Jan 98 - Dec 01*

Genre	% VHS ST priced A	B	Total Released A	B
Act/Adv	33.3	6.7	69	30
Child/Fam	100.0	100.0	33	13
Comedy	33.7	11.4	83	79
Drama	21.4	2.1	42	48
Horror/Sus	7.7	7.9	39	38
Romance	0.0	0.0	8	13
Sci-Fi	55.6	13.3	9	15
Total	35.8	13.4	285	238

*Tabulations compiled by author using data from Rentrak Corporation. A titles grossed at least 40 million dollars in theatrical revenues. B titles grossed between 15 and 40 million dollars in theatrical revenues. Table includes all A and B titles released during the relevant time period, including those available on revenue-sharing terms.

Table 3: All A and B Titles Released on DVD, Jan 00 - Dec 01*

Genre	% DVD ST priced		Total Released	
	A	B	A	B
Act/Adv	100.0	100.0	27	11
Child/Fam	100.0	100.0	12	2
Comedy	100.0	100.0	27	37
Drama	100.0	96.0	19	25
Horror/Sus	100.0	100.0	13	16
Romance	100.0	100.0	4	5
Sci-Fi	100.0	100.0	4	7
Total	100.0	99.0	106	103

*Tabulations compiled by author using data from Rentrak Corporation. A titles grossed at least 40 million dollars in theatrical revenues. B titles grossed between 15 and 40 million dollars in theatrical revenues. Table includes all A and B titles released during the relevant time period, including those available on revenue-sharing terms.

Table 4: Empirical Evidence on the Growth of DVD

(in millions)	1999	2000	2001
DVD Households (1)		12	24
Total Expenditures:			
DVD Rentals (2)	300	569	1,400
DVD Sales (3)	1,300	3,200	5,300
Growth Rate over Previous Year			
DVD Rentals (2)		90%	146%
DVD Sales (3)		146%	66%
Expenditures in my data			
DVD Rentals (4)		9.7	43.0
DVD Sales (4)		0.6	5.1

(1) VSDA 2002 Annual Report, pg. 3. Source: Kagan World Media; www.adamsmediaresearch.com.
(2) VSDA 2002 Annual Report, pg. 3. Source: Vidtrac; www.adamsmediaresearch.com.
(3) VSDA 2002 Annual Report, pg. 13. Source: Adams Media Research.
(4) Author's calculations. (2000-2001 New Releases, Sample Stores Only)

Table 5: Timing of Rentals and Sales: Cumulative Percentages by Month

	VHS			DVD		
	Rentals	Used Sales	New Sales	Rentals	Used Sales	New Sales
Panel 1: Rental Priced Titles (N = 12):						
Month 1	39.9	0.3	3.0	44.7	7.7	23.4
Month 2	62.2	1.2	7.5	63.6	20.8	46.1
Month 3	77.2	14.7	11.0	75.1	37.9	66.7
Month 4	83.7	29.6	13.3	80.3	48.3	76.6
Month 5	88.1	44.4	14.7	84.8	56.7	83.2
Month 6	94.7	57.1	37.5	93.3	71.3	90.9
Month 7	100.0	69.6	74.4	100.0	84.2	94.5
Month 8	100.0	79.5	89.4	100.0	91.4	96.2
Months 9+	100.0	100.0	100.0	100.0	100.0	100.0
Panel 2: Sell-through Priced Titles (N = 29):						
Month 1	44.1	1.8	50.1	44.4	5.9	17.4
Month 2	65.8	15.7	60.3	64.3	20.6	34.3
Month 3	76.9	38.5	65.2	77.7	42.2	61.3
Month 4	85.1	54.1	69.2	83.8	55.7	74.8
Month 5	88.1	65.8	71.4	88.2	67.6	84.2
Month 6	94.7	75.3	90.1	94.7	79.5	91.3
Month 7	100.0	84.6	95.7	100.0	87.3	94.1
Month 8	100.0	92.8	98.2	100.0	93.5	96.4
Months 9+	100.0	100.0	100.0	100.0	100.0	100.0

Table 6: Monthly Average Prices of Rentals and Sales

	VHS			DVD		
	Rentals	Used Sales	New Sales	Rentals	Used Sales	New Sales
Panel 1: Rental Priced Titles (N = 12):						
Month 1	3.00	11.84	97.74	3.04	8.45	16.87
Month 2	3.03	7.81	100.44	3.18	9.10	16.48
Month 3	3.01	7.92	97.65	3.29	8.33	16.53
Month 4	2.97	9.15	88.60	3.28	9.02	16.27
Month 5	3.03	8.44	96.40	3.23	9.28	15.60
Month 6	2.72	7.05	19.23	2.78	9.79	14.85
Month 7	2.72	6.29	18.80	2.78	9.93	14.90
Month 8	2.72	5.72	18.27	2.78	9.18	14.60
Months 9+	2.72	5.98	26.68	2.78	9.57	15.47
Panel 2: Sell-through Priced Titles (N = 29):						
Month 1	3.01	7.79	17.48	3.05	10.40	19.50
Month 2	3.17	7.70	18.85	3.53	11.36	17.08
Month 3	3.18	7.36	20.30	3.67	11.27	15.67
Month 4	3.15	7.11	18.47	3.86	10.96	15.47
Month 5	3.12	7.00	18.34	3.80	10.87	14.60
Month 6	2.74	6.42	13.53	3.09	9.87	13.23
Month 7	2.74	6.41	14.34	3.09	9.87	14.01
Month 8	2.74	6.29	14.24	3.09	9.46	12.54
Months 9+	2.74	6.00	15.19	3.09	9.87	11.61

Table 7: Weighted Quantities of Rentals and Sales

	VHS			DVD		
	Rentals	Used Sales	New Sales	Rentals	Used Sales	New Sales
Panel 1: Rental Priced Titles (N = 12):						
Total per Title ('000)	1112.2	20.3	0.2	129.6	3.7	1.5
Weighted Total per Title	4054.9	56.8	248.5	491.7	10.4	136.6
Ratio, Weighted Sales/Rentals			7.5%			29.9%
Panel 2: Sell-through Priced Titles (N = 29):						
Total per Title ('000)	910.5	39.2	0.5	131.8	5.0	0.9
Weighted Total per Title	3319.5	109.8	327.3	500.1	14.0	158.4
Ratio, Weighted Sales/Rentals			13.2%			34.5%

Table 8: Estimated Parameter Values

	VHS				DVD (VHS was:)			
	Rental Priced		Sell-through Priced		Rental Priced		Sell-through Priced	
Taste Parameters (se):								
Store Size	-0.19	(0.003)			-0.25	(0.003)		
Median Income	0.00	(0.000)			-0.01	(0.001)		
%Married/kids	0.01	(0.001)			0.01	(0.002)		
%Married/kids*(Kid Movie)	-0.01	(0.002)			0.00	(0.003)		
% Suburban	0.47	(0.030)			0.25	(0.044)		
Avg. $\lambda (\equiv \exp(x'\beta))$	1.08				1.13			
α	0.68	(0.003)			0.62	(0.006)		
$E_i[E[\nu_i|x_i,\theta]]$	1.16				1.19			
Avg. Quality Parameters (avg. se):								
δ_r	1.41	(0.038)	1.20	(0.072)	0.95	(0.044)	0.78	(0.055)
δ_u	1.70	(0.038)	1.45	(0.072)	1.36	(0.045)	1.12	(0.056)
$\rho\delta_s$	1.87	(0.038)	–		–		–	
δ_s	2.45	(0.038)	2.04	(0.072)	1.70	(0.044)	1.40	(0.055)
δ_r/δ_s	0.58		0.58		0.56		0.56	
Other Parameters:								
ρ	0.71		–		–		–	
τ	23.72		16.96		16.12		15.65	
μ_r	-0.04		2.10		1.33		0.91	
μ_u	8.46		7.71		10.33		11.51	
μ_s (period 1)	43.55		9.45		7.77		10.18	
μ_s (period 2)	4.09		–		–		–	

Table 9: Counterfactual Exercises, VHS

	Actual	Current
Rental Priced Titles (12):		
p_w^r	$65.52	65.52
p_s (per 1)	109.07	109.07
p_s (per 2)	20.45	20.45
p_u	8.46	8.46
p_r	2.92	2.92
% New (per 1)	0.11	0.18
% New (per 2)	0.24	0.00
% Used	0.18	1.31
% Rent	12.54	22.62
π_{stud}, per Mkt. (000s)	8.26	14.20
π_{ret}, per Mkt. (000s)	1.59	3.30
Local Mkt. Size (000s)	19.41	19.41
% Change C.S.	–	–
Sell-through Priced Titles (29):		
p_w^r	$14.47	14.47
p_s (per 1)	23.92	23.92
p_s (per 2)	–	–
p_u	7.71	7.71
p_r	2.94	2.94
% New (per 1)	0.66	0.39
% New (per 2)	–	–
% Used	0.36	0.91
% Rent	10.79	17.91
π_{stud}, per Mkt. (000s)	2.94	3.29
π_{ret}, per Mkt. (000s)	3.89	7.86
Local Mkt. Size (000s)	18.52	18.52
% Change C.S.	–	–

Table 10: Counterfactual Exercises, DVD

	Actual	Current
VHS was Rental Priced (12):		
p_w^r	$15.57	15.57
p_s (per 1)	23.34	23.34
p_s (per 2)	–	–
p_u	10.33	10.33
p_r	2.82	2.82
% New (per 1)	2.07	1.04
% New (per 2)	–	–
% Used	0.14	1.05
% Rent	8.44	16.23
π_{stud}, per Mkt. (000s)	1.29	1.42
π_{ret}, per Mkt. (000s)	0.77	1.43
Local Mkt. Size (000s)	3.37	3.37
% Change C.S.	–	–
VHS was Sell-through Priced (29):		
p_w^r	$17.11	17.11
p_s (per 1)	27.29	27.29
p_s (per 2)	–	–
p_u	11.51	11.51
p_r	2.83	2.83
% New (per 1)	1.35	0.73
% New (per 2)	–	–
% Used	0.16	0.98
% Rent	6.78	14.19
π_{stud}, per Mkt. (000s)	1.33	1.69
π_{ret}, per Mkt. (000s)	0.96	1.83
Local Mkt. Size (000s)	4.32	4.32
% Change C.S.	–	–