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

Julie Holland Mortimer[*†]

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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.

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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 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. 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 and choose to rent rather than purchase, upstream firms (movie studios) should again adopt a rental-pricing strategy in order to discriminate between the institutional and individual purchasers.

An important motivation for the adoption of sell-through pricing of DVDs in the U.S. market is the restrictions imposed by the U.S. Copyright Act. In many other countries, DVDs are simply sold at different prices to rental stores and individual buyers simultaneously. Thus, there is no need to consider intertemporal price discrimination. This paper seeks to answer the following questions. First, what effect do the restrictions 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 'first-best' 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.

Essentially, the first question concerns the welfare effects of second- versus third-degree price discrimination, but it is motivated by the policy question of the effects of the Copyright Act. The Copyright Act effectively eliminates the possibility of third-degree price discrimination, because the copyright holder cannot restrict activity on a product purchased by an individual. Thus, market segmentation cannot be effective–individual buyers would merely arbitrage away the difference by entering the rental market as retailers. Thus, upstream firms have instead used intertemporal, second-degree price discrimination through the use of rental pricing.

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

3

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 to two alternatives: market segmentation (which addresses the question of the effects of copyright law), and 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 or not. In sections 4 and 5 I describe the dataset and modify the demand system to incorporate some institutional details and I estimate quality levels and other parameters. 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 46 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 in the performance of a title (cross-market variation). I allow both the quality and taste parameters to vary according to format, and I describe the implied quality differences of

4

the DVD format. Finally, section 6 provides the results of the 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.

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.[1] 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 the next section. 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

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[1]VSDA Annual Report, 1999.

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 distribution arm of a movie studio for ownership of a pre-recorded videocassette tape of a movie.[2] 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.[3] 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.[4] 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

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[2]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.

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

[4]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.

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 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 permitted 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. The model

7

of consumer demand considers demand for a single product that is vertically-differentiated according to whether or not the product is rented or purchased.[5] 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 due to the need to discriminate between markets intertemporally.

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. 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.[6]

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 $\nu_i \delta_r - p_r > 0$. Thus, 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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[5]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.

[6]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

$$
\begin{aligned}
N(1 - F(\tilde{\nu})) & \quad \text{in purchase market} \\
N(F(\tilde{\nu}) - F(\hat{\nu})) & \quad \text{in rental market}
\end{aligned}
\tag{2}
$$

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. For example, 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:

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

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

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,

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

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

These specifications assume that each videocassette tape or DVD produces τ rentals.[7] 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 $p_r = p_w^r/\tau + \mu_r$.[8] Taking both the sales and rental markets, the upstream firm maximizes:

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

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[7]In later sections of the paper, I distinguish between the VHS and DVD markets, and τ is allowed to vary across formats, along with other parameters of the model.

[8]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.

where $\tilde{\nu} = \tilde{\nu}(p_s, p_r, \delta_s, \delta_r)$ and $\hat{\nu} = \hat{\nu}(p_r, \delta_r)$ as before, and $F(\nu)$ is the cumulative distribution function of ν.

3.2.1 Example

To provide a simple example of the pricing decision, I consider the case in which $\nu \sim U[0, 1]$, $N = 1$, and $\mu_r = \mu_s = 0$. I assume there is a single upstream firm and a single, price-taking retailer, and solve for the optimal prices in three cases.[9]

Market Segmentation (Third-degree Price Discrimination)

First, I allow for different prices in the 2 markets simultaneously. This should be the 'first-best' solution for the studio (assuming it can always choose $p_s = p_r$ too). Prices in this case are:

$$p_w^{r*} = \frac{1}{2} \cdot (c + \tau \delta_r) \text{ and } p_w^{s*} = \frac{1}{2} \cdot (c + \delta_s)$$

Notice that the price charged to rental stores accounts for the fact that each tape produces τ rentals. Prices are increasing in costs, τ and the quality parameters.[10] 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 (and used by) firms in many other countries.

No Price Discrimination

The second case considers the pricing problem in the absence of price discrimination (sell-through pricing). I solve for a single wholesale price, which I denote as p_w. Again, when ν is distributed according to a standard uniform:

$$p_w^* = \frac{1}{2} \cdot (c + \frac{\tau^2 \delta_r (\delta_s - \delta_r)}{(\tau^2 \delta_r - 2\tau \delta_r + \delta_s)})$$

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[9]In the empirical work, I relax all of these assumptions with the exception of the assumption of a monopolistic upstream firm (studio).

[10]Of course, the precise functional form depends on the distributional assumption on ν. The hope here is merely to provide some intuition for firms' decision-making process.

The (single) wholesale price is a function of the qualities of the two goods (rental versus purchase), cost (c), and the "rental technology" (τ).

Intertemporal Discrimination (Second-degree Price Discrimination)

The third case considers intertemporal price discrimination (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. It 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 $\rho < 1$. 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]

Suppose that individual consumers do not have access to sales in the first period, perhaps because tapes in this period must be ordered through video retailer distributors which are difficult to access for individual consumers. Thus, consumers only consider renting in the first period, or purchasing in the second period. In this case, re-solving for the firm's optimal prices yields:

$$p_w^{r*} = \frac{1}{2} \cdot (c + \tau\delta_r) \text{ and } p_w^{s*} = \frac{1}{2} \cdot (c + \rho\delta_s)$$

Not surprisingly, the upstream firm adjusts its price to reflect the reduced quality in the sales market resulting from delaying the release of the title for purchase at the sell-through price. The price in the rental market is unchanged.

The purpose of showing these solutions is simply to establish some intuition for pricing rules in a simple setting. Strictly speaking however, consumers could most likely purchase at the high price (p_w^{r*}) in period 1 by special ordering tapes through their local retailer. In

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[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.

the empirical estimation I allow for such purchases, which do occur occasionally in the data. Incorporating these purchases leads to a demand system with three products: first-period purchase, second-period purchase, and rental, with associated quality levels of $\delta_s, \rho\delta_s$, and δ_r.[12]

3.2.2 Numerical Results of Example

For each of the three cases outlined above, one can estimate prices and market shares for the purchase and rental products of a title if the parameters $(N, \tau, c, \delta_s, \delta_r, \rho)$ are known. The top panel of table 5 provides solutions in the three cases when ν_i is uniformly distributed over the interval (0,1), $N = 1, \tau = 20, c = 2, \delta_s = 27.6, \delta_r = 6.9$, and ρ takes the value 0.5 or 0.95. Note that at these parameter values, consumers receive one-fourth of the value of owning the movie by just renting it once.

The first column in table 5 gives solutions to the problem when the upstream firm can charge different prices to rental stores and end-users. The firm cannot do better than this through the use of intertemporal price discrimination, so I refer to this as the 'first-best' option for the upstream firm. The firm optimally sets the price for sales to video rental stores at $70.00. Video rental stores set the price of a rental equal to average cost (mark-ups are assumed to be zero), which in this example is $3.50. The price in the purchase market is $14.80, and at these prices, 45 percent of end-users purchase and 4 percent rent. Variable profit to the upstream firm is 5.9, and in this example, retail firms earn zero profits. In the second case with a single wholesale price, the upstream firm charges $12.37. Video rental stores charge a price equal to average cost (the mark-up is assumed to be zero), which now is $0.62. This outcome may be appropriate for thinking about purchases and rentals of children's VHS tapes, for example. Total profits to the upstream firm are now 4.7. The percentage change in consumer utility from column 1 to column 2 is 62.1 percent: consumers are better off under sell-through pricing than under direct market segmentation.

The third and fourth columns of table 5 gives results for the case in which the upstream firm segments intertemporally; first selling to video rental stores and later selling to end-users in the sales market. I consider first the case in which the product is only half as valuable after waiting until the second period ($\rho = 0.5$). The depreciation of the good

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[12]In this case, consumers purchase in period 1 if $\nu_i > \frac{p_w^{r*} - p_w^{s*}}{(1-\rho)\delta_s}$. Optimal prices p_w^{s*} and p_w^{r*} may also be solved analytically in this example (and the above expression written in terms of model parameters), although the solutions are somewhat messier, and thus less intuitive for the purposes of a 'simple' example.

is reflected in the price charged in the sales market, which falls to \$7.90. The price of a rental is unchanged, but now 36 percent of consumers purchase and 13 percent rent. Total variable profit to the upstream firm is 2.6, which is less than the profit of 4.7 attained by setting a single price for both markets. Consumer surplus is 56.6 percent lower compared to the 'first-best' outcome under market segmentation in column 1. In the fourth column, the relative discount factor is $\rho = .95$. Now the price of a purchased tape is \$14.11, the rental price is unchanged, 25 percent of consumers purchase, while 4 percent rent. However, variable profit is now 5.6; higher than the profit attained by a sell-through pricing strategy. Consumer surplus is now 5.8 percent lower compared to the market segmentation outcome in column 1. At these parameter values, consumers are worse off under second-degree price discrimination than they would have been under third degree price discrimination with a less restrictive copyright law. At these parameter values, it pays to use second-degree price discrimination when quality does not decay quickly (ρ is high). When quality does decay quickly (for example, $\rho = 0.5$), it is more profitable to sell at a single price.

The bottom panel of table 5 provides solutions under the same conditions, except that now I assume the relative value of renting, δ_r is only one-tenth of the value of purchasing, δ_s (ie., $\delta_r = 2.76$). Under this condition, sell-through pricing is more profitable under either value of ρ. Profits under the case of no price discrimination are 5.8, compared to 5.6 using second-degree price discrimination with $\rho = 0.95$. Consumer surplus is 9.4 percent higher without price discrimination, compared to the outcome under market segmentation. However, consumer surplus is lower under second degree price discrimination when making the same comparison.

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 similar demand and supply equations in estimation. Second, the numerical example is intended to motivate and identify the parameters that affect the pricing decisions of the upstream firm. It is also intended to demonstrate the potential welfare effects of various pricing regimes for consumers. I show that the quality decay rate can be an important determinant of the optimal pricing regime. Also, the relative value of renting compared to purchasing can affect the optimal pricing strategy. Finally, it may also be the case that the parameters of the distribution of consumer tastes affect the choice of the optimal pricing strategy. This is somewhat more difficult to motivate in the context of a simple uniform distribution.

When estimating the model on actual data, however, I use a more natural distributional assumption and allow the parameters of the distribution of tastes to vary across VHS and DVD hardware bases. This allows me to check, first, how the distribution of tastes varies across the formats, and second, how this affects the optimal pricing policy. Now I turn to a description of the data, and following that, I describe the estimation methodology.

4 Data 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 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.[13]

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 because 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

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[13]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.

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.[14] 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 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 46 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 US Census data 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

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

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 clearly 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 Video Software Dealers Association (VSDA) 2002 Annual Report and Adams Media Research on quarterly DVD penetration rates. Unfortunately, these penetration rates are only available at a national level.[15] I assume that penetration occurs uniformly across local markets by quarter; this assumption is actually supported by the VSDA annual report and other industry reports. 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).

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[15]I am also investigating the possibility of acquiring more refined data on penetration rates, possibly from the Consumer Electronics Manufacturers Association.

5 Identification and Estimation

5.1 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 the discount rate and the parameters of the distribution of consumer tastes.)

Table 6 provides summary statistics from the data on both the quantity and timing of rentals and sales on both formats. For the 46 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 46 titles, 31 are sell-through priced (in the lower half) while 15 are rental-priced (in the 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). Roughly 80 to 85 percent of all rentals occur in the first 17 weeks (4 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 17, 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,

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in table 7, there is no difference in the price of used tapes over time; in fact, the average price of a used tape is actually higher for DVDs in later months than in early months. The timing of rentals and used sales are very similar across the four quadrants of table 6.

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 20 percent) occur during the first 17 weeks (four months). In contrast, roughly three-fourths of all new sales take place in the first four months for sell-through priced VHS titles and all DVD titles. I classify sales occurring during the first 4 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 4 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 6.

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 nearly one-fourth 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 20. 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 supported by examining prices over time.

Prices of rentals and sales by month are shown in Table 7, which is also organized according to the pricing pattern use 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. Prices of rentals do not change after month 5, because I aggregate rental transactions that occur after week 20 and report the average price. Prices of used sales are also slightly higher for DVDs, and there are not 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 four months (before sell-through re-pricing occurs) range from \$37 to \$87. In contrast, prices of new sales in period 2 (months 5 and higher) average between \$11 and \$16. Prices in the second period look very similar to prices of new sales for sell-through priced VHS's and all DVDs. Most new sales of sell-through priced VHS and all DVDs occur in the first four months, but prices do not vary much across the months.

Table 8 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 VHS's: 29.6 and 32.6 percent of rentals for DVDs versus 15.7 and 7.6 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 for these sets of titles is 3 percent for DVDs (32.6 versus 29.6 percent). Overall levels of DVD activity 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. 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 15.7 percent of rentals for sell-through priced titles, compared to 7.6 percent of rentals for rental-priced titles. The difference is due to both lower levels of rentals as well as higher levels of sales.

5.2   Identification of Quality

The model of demand that is used in estimation is similar to the simple theory model introduced in section 3, except with two small twists. First, there is a third 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 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. The second twist is that I allow for purchases of the very high-priced VHS tapes by individual buyers in period 1. Thus, for rental-priced titles, the possible quality levels are $\delta_r, \delta_u, \rho\delta_s$, and δ_s. I adopt a two-period model for two reasons. First, I hope that the patterns of rentals and sales in table 6 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.

The parameters to be estimated include the vector of product qualities for each title, and parameters of the distribution of ν. I also need to estimate the discount factor ρ, market size N and the rental technology parameter τ, and mark-ups μ. I first offer a discussion of the identification of the quality parameters, and then describe the estimation methodology.

The identification strategy identifies the quality of a movie off of cross-title variation in the overall market shares of rentals and sales across many local markets in the spirit of Bresnahan (1987), Berry, Levinsohn and Pakes (1995) and Nevo (2000). 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.[16]   Geographically, I define a market to include all households located within a zipcode.[17] This market definition leaves more than 2,000 local markets. The large number of geographic markets allows me to specify a separate quality parameter for each product. Thus, I do not use a characteristics approach,

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[16]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 <u>rental</u> of *Saving Private Ryan* to compete with a <u>purchase</u> 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.

[17]See Mortimer (2001) for a discussion of the use of zipcodes to define geographic markets in this industry.

but rather, I estimate 46 times 3 times 2 quality parameters: this is the number of titles (46) multiplied by the level of purchase (3 choices: rental, and used or new purchase) multiplied by format (VHS or DVD). Recall that once a household owns a DVD player, I assume that they consume only rentals and sales of DVDs (not VHS tapes). I do not rank DVD and VHS qualities: I estimate quality parameters separately for the two formats for each title. For rental-priced VHS titles, I also estimate a quality parameter for second-period purchases of new tapes, so in that case, there are 46 times 4 times 2 quality parameters to estimate. note that the use of product dummies is strictly more general than a characteristics approach, and is possible here because of the large number of local markets in the dataset.

I specify the quality level for renting and purchasing separately for the two different formats. The quality of a purchase depends on whether or not purchase is delayed until period 2. Purchases of sell-through priced titles (including all DVD releases) are all assumed to occur without a discount due to time delay, since such titles are available at a single price immediately upon release. The quality levels for a title which is sell-through priced on both the VHS and DVD formats are denoted:

$$
\begin{array}{llll}
\delta_r^v & \text{if rent VHS} & \delta_r^d & \text{if rent DVD} \\
\delta_u^v & \text{if purchase used VHS} & \delta_u^d & \text{if purchase used DVD} \\
\delta_s^v & \text{if purchase VHS} & \delta_s^d & \text{if purchase DVD}
\end{array}
\tag{3}
$$

The quality levels for a title which is rental-priced on the VHS format (and sell-through priced on the DVD format) are:

$$
\begin{array}{llll}
\delta_r^v & \text{if rent VHS} & \delta_r^d & \text{if rent DVD} \\
\delta_u^v & \text{if purchase used VHS} & \delta_u^d & \text{if purchase used DVD} \\
\rho\delta_s^v & \text{if purchase VHS in period 2} & & \\
\delta_s^v & \text{if purchase VHS in period 1} & \delta_s^d & \text{if purchase DVD}
\end{array}
\tag{4}
$$

Thus, for each title, I estimate a vector of 6 quality parameters if the VHS format was sell-through priced, or a vector of 7 quality parameters if the VHS format was rental-priced. Once these parameters are estimated (using over 2,000 local markets), I can also calculate the ratio of different quality levels for each title across formats. For example, consider the ratio of the quality of renting a DVD to the quality of renting a VHS of the same title; denote this quality ratio ω. I can calculate an ω_j for each title, and I can summarize the average percentage quality upgrade for DVD rentals compared to VHS rentals (for this

group of titles) as the average of the ω_j's (denoted simply as ω). The intuition for ω is that renting the same title on the DVD format allows for better quality picture and sound, and possibly the opportunity to utilize extra features included on the DVD format, such as commentaries or documentaries. If video stores implement different rental policies (such as allowing DVDs to be rented for a longer or shorter period of time), this will also be included in ω. I cannot separately identify these different effects on the rental quality of DVDs.

Similarly, I can calculate an average ratio of the quality of purchasing a used DVD to the quality of purchasing a used VHS, which I denote as σ; and also, an average ratio of the quality of new (period 1) purchases on the two formats, which I denote as ϕ. The intuition for ϕ is that owning a DVD allows consumers to take advantage of the additional functionality of the DVD format compared to VHS, such as added durability, smaller storage size, and the ability to play the movie on a home computer or laptop while traveling.

Finally, one might like to estimate the discount parameter ρ. As before, 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. One might be interested in 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 on VHS vs. a rental price 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.

5.3 Estimation

The consumer demand model provides estimates of market shares which are functions of data (including title dummies, local market sizes, DVD penetration rates and local demographics) and parameters (including quality parameters, and parameters of the distribution of consumer tastes, ν_i). The last section discussed identification of the quality parameters, which are functions of title dummies. The parameters of the distribution of consumer tastes

are functions of local demographics. At a fundamental level, separately identifying these two sets of parameters (quality and consumer tastes) relies on the fact the quality parameters shift across title dummies, but taste parameters shift across local market characteristics for a given title. I specify a Weibull distribution for ν, with parameters $\lambda \equiv \exp(X'_m\beta)$ and α. The probability density function is given by $f(\nu) = \lambda\alpha\nu^{(\alpha-1)}\exp(-\lambda\nu^\alpha)$. The parameters to be estimated are: $\Theta \equiv (\delta_r, \delta_u, \delta_s, \beta, \alpha, \rho)$. I back out the parameters $N, \tau, \mu, \omega, \sigma$, and ϕ separately once I have estimated the first set of parameters.

A market is defined to be a zipcode-title-format triple. Thus, conditional on which hardware they own, consumers decide whether to purchase or rent a given title in their local market. Profit functions for all firms are assumed to be additively separable across titles. I abstract from potential weekly variation in the timing of rentals and sales, and consider only two time periods. The time periods are: before and after sell-through re-pricing, which only occurs for rental-priced titles on the VHS format. Sell-through re-pricing is assumed to occur after four months. The predicted market shares are calculated based on the distributional assumption on ν; thus, market shares as a function of the model's parameters are:

$$
\begin{aligned}
s_s =&\ N \cdot \exp\left(-\exp(X\beta)\left(\frac{p_s-p_u}{\delta_s-\delta_u}\right)^\alpha\right) \\
s_u =&\ N \cdot \left(-\exp\left(-\exp(X\beta)\left(\frac{p_s-p_u}{\delta_s-\delta_u}\right)^\alpha\right) + \exp\left(-\exp(X\beta)\left(\frac{p_u-p_r}{\delta_u-\delta_r}\right)^\alpha\right)\right) \\
s_r =&\ N \cdot \left(-\exp\left(-\exp(X\beta)\left(\frac{p_u-p_r}{\delta_u-\delta_r}\right)^\alpha\right) + \exp\left(-\exp(X\beta)\left(\frac{p_r}{\delta_r}\right)^\alpha\right)\right) \\
s_0 =&\ N \cdot \left(1 - \exp\left(-\exp(X\beta)\left(\frac{p_r}{\delta_r}\right)^\alpha\right)\right)
\end{aligned}
\tag{5}
$$

where δ_r, δ_u and δ_s represent the quality levels of the appropriate format (ie., δ_r takes the value δ_r^v and δ_r^d for VHS and DVD formats respectively.) Prices are denoted with the same subscripts, and apply separately to VHS and DVD formats. Local demographic shifters (X) include median income, the percent of the area that is suburban, store size, and number of people. One could also interact observable title characteristics with local demographics; future versions will check the robustness of the results to such interactions.

Most markets rent and sell used tapes for the 46 titles in the analysis. However, many markets have zero market share for new sales.[18]   When I observe zero market share for

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[18]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.

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 4 months (17 weeks) before re-pricing, and they are assigned the re-priced SRP in months 5 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, market shares as a function of the model's parameters are:

$$
\begin{aligned}
s_{s1} = {} & N \cdot \exp\left(-\exp(X\beta)\left(\tfrac{p_w - p_s}{(1-\rho)\delta_s}\right)^{\alpha}\right) \\
s_{s2} = {} & N \cdot \left(-\exp\left(-\exp(X\beta)\left(\tfrac{p_w - p_s}{(1-\rho)\delta_s}\right)^{\alpha}\right) + \exp\left(-\exp(X\beta)\left(\tfrac{p_s - p_u}{\rho\delta_s - \delta_u}\right)^{\alpha}\right)\right) \\
s_u = {} & N \cdot \left(-\exp\left(-\exp(X\beta)\left(\tfrac{p_s - p_u}{\rho\delta_s - \delta_u}\right)^{\alpha}\right) + \exp\left(-\exp(X\beta)\left(\tfrac{p_u - p_r}{\delta_u - \delta_r}\right)^{\alpha}\right)\right) \\
s_r = {} & N \cdot \left(-\exp\left(-\exp(X\beta)\left(\tfrac{p_u - p_r}{\delta_u - \delta_r}\right)^{\alpha}\right) + \exp\left(-\exp(X\beta)\left(\tfrac{p_r}{\delta_r}\right)^{\alpha}\right)\right) \\
s_0 = {} & N \cdot \left(1 - \exp\left(-\exp(X\beta)\left(\tfrac{p_r}{\delta_r}\right)^{\alpha}\right)\right)
\end{aligned}
\tag{6}
$$

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 $N_{m,q}^{VHS}$ 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:

$$
\begin{aligned}
N_{m,q}^{VHS} = {} & [0.90 \cdot HH \cdot (1 - DVD_q)]/STORES_{m,y} \\
N_{m,q}^{DVD} = {} & [HH \cdot DVD_q]/STORES_{m,y}
\end{aligned}
\tag{7}
$$

where 0.90 is the national penetration of VCRs, assumed to be constant across markets, the variable HH is the number of households in the market (defined to be a 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.[19] The variable $STORES_{m,y}$

---

[19]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.

is the number of video specialty stores in the zipcode in a particular year. Typically, I observe roughly 1 of 3 stores in each zipcode neighborhood. Unfortunately, I don't 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.[20]

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. For example, in the case of the VHS format, total sales can be calculated from table 8 as $(0.2 + 26.1) \cdot 15$ titles $+ (0.6 + 40.9) \cdot 31$ titles). All used sales are assumed to take place at video specialty stores, so I subtract total used sales, which are given by used sales multiplied by the number of video specialty stores listed in the phonebook data: $(26.1 + 40.9) \cdot 2.8$ stores. Total weighted sales minus total used sales (weighted only by phonebook listings) gives weights for new sales of 0.022 for DVDs and 0.008 for VHS tapes. Now I can write down the relevant market size for each store-format-product as:

$$
\begin{aligned}
N_{r,m,q}^{VHS} &= 0.768 \cdot [0.90 \cdot HH \cdot (1 - DVD_q)]/STORES_{m,y} \\
N_{u,m,q}^{VHS} &= [0.90 \cdot HH \cdot (1 - DVD_q)]/STORES_{m,y} \\
N_{s,m,q}^{VHS} &= 0.008 \cdot [0.90 \cdot HH \cdot (1 - DVD_q)]/STORES_{m,y} \\
N_{r,m,q}^{DVD} &= 0.738 \cdot [HH \cdot DVD_q]/STORES_{m,y} \\
N_{u,m,q}^{DVD} &= [HH \cdot DVD_q]/STORES_{m,y} \\
N_{s,m,q}^{DVD} &= 0.022 \cdot [HH \cdot DVD_q]/STORES_{m,y}
\end{aligned}
\tag{8}
$$

---

[20]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, and $SIZE$ is the size of the store. 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.

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 5 in terms of the quality parameters as:

$$
\begin{aligned}
\delta_r =\ & p_r[-\ln(1 - \tfrac{s_0}{N}) \cdot \exp(-X\beta)]^{-(1/\alpha)} \\
\delta_u =\ & p_r[-\ln(1 - \tfrac{s_0}{N}) \cdot \exp(-X\beta)]^{-(1/\alpha)} + (p_u - p_r)[-\ln(\tfrac{1-s_r-s_0}{N}) \cdot \exp(-X\beta)]^{-(1/\alpha)}] \\
\delta_s =\ & p_r[-\ln(1 - \tfrac{s_0}{N}) \cdot \exp(-X\beta)]^{-(1/\alpha)} + (p_u - p_r)[-\ln(\tfrac{1-s_r-s_0}{N}) \cdot \exp(-X\beta)]^{-(1/\alpha)}] \\
& + (p_s - p_u)[-\ln(\tfrac{1-s_s}{N}) \cdot \exp(-X\beta)]^{-(1/\alpha)}]
\end{aligned}
$$

(9)

where once again, the quality parameters take the values of δ_r and δ_s that are format-specific (VHS or DVD) and N takes the relevant value according to equation 8.[21] The quality parameters for rental-priced VHS titles can be solved similarly to incorporate period 1 and period 2 sales. Details are provided in Appendix A.

The estimation of separate δ_s, δ_u and δ_r for each movie relies essentially on movie fixed-effects, rather than on projecting movie quality onto observable movie characteristics. The advantage of projecting quality onto product space is that with relatively few observable movie characteristics (box office category, genre, month of release and rating), product dummies can pick up important unobservable characteristics that influence firms' pricing decisions and consumer demand for a movie. This is strictly more general than projecting quality onto characteristic space. One potential disadvantage is that prediction for new movies is less straightforward: in order to extrapolate any results to the release or pricing decision of a new title, one needs to know its δ vector. I address this issue by regressing the fitted δ's on observable movie characteristics in a second stage regression after obtaining the estimated δ vectors.

When constructing the moment conditions, equation 9 implies that $E[\delta_{r,m} - p_{r,m}[-\ln(1-$

<hr />

[21]Note that there is no difference between using the weights to adjust N down, or using the weights to adjust market shares (s) up.

26

$\frac{s_{0,r,m}}{N^{VHS}_{r,m,q}}) \cdot \exp(-X_m\beta)]^{-(1/\alpha)}] = 0$ and so on, for $\delta_{u,m}$ and $\delta_{s,m}$ and across formats. I denote this

term $\xi_{r,m}$, which represents deviations in the local market share of rentals for a particular

title. Similarly, I define $\xi_{s,m}$ as deviations of local market shares in the sales market, etc.

One must worry that this market-specific valuation of the product may be correlated with

local deviations in price. Following Hausman (1997) and Nevo (2000), I assume that market-

specific valuation of the product is uncorrelated across markets. I use the prices of the title

in other markets (zipcodes) as instruments. The intuition for the use of these instruments

is that the prices of the title in two markets are correlated due to a common marginal cost

(such as shipping costs or unobservable volume discounts). By assumption, the correlation

in price is not due to correlations in market-specific valuation of the product across markets.

I define the set of instrumental variables as $W_{r,m}$ (or $W_{s,m}$ for sales, etc.), and it consists

of the price of the same title at other zipcodes.[22]

So far, I've discussed the estimation methodology for the parameters $(\delta_r, \delta_s, \beta, \alpha, \rho, N)$.

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 and pricing

type (rental or sell-through pricing) in order to capture the different cost structures 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.[23] 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. Details

are provided in Appendix A.

6 Estimation Results and Welfare Analysis

Table 9 provides a few parameters of the model. Estimated quality and taste parameters

are coming soon. The τ parameter indicates that VHS inventory is used more intensively

for titles that are rental-priced, producing 24.6 rentals per tape compared to 16.9 rentals per

---

[22]One could also try instruments that vary over time, such as the number of titles released by the same studio during the month of release of the current title. Robustness tests of alternative specifications will be incorporated in future versions of the paper.

[23]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 do not observe these, and assume that retailers pay the usual wholesale price.

tape for sell-through priced titles. DVDs show almost no difference in the rental technology across the two sets of titles, producing 19.0 and 18.2 rentals respectively. Retail mark-ups are higher for the sell-through priced VHS titles and for DVDs: around $2 compared to $0.87 for rental-priced titles on the VHS format. Sales mark-ups are very high during the first period for rental-priced VHS (with an average mark-up of $33), but are around $3 - $4 for sell-through priced VHS or VHS sales after re-pricing, and around $1 - $2 for the DVD format.

6.1   Counterfactual Experiments and Welfare Analysis

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 continue to be the profit-maximizing pricing regime as hardware adoption evolves. In order to answer this question, I use the estimated parameters in (a completed version of) table 9 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 to reflect the possible higher quality of the new format). 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.

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 different 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.

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. 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 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 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 simulated results of 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. 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 conjunc-

tion 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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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		Total Released	
	A	B	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: Prices and Market Shares, Numerical Example:

$$\nu \sim u[0,1], N = 1, \tau = 20, c = 2, \delta_s = 27.6$$

	(1) Market Segmentation	(2) Sell-thru Pricing	(3) Rental Pricing $\rho = .50$	(4) Rental Pricing $\rho = .95$
Panel 1: $\delta_r = \delta_s/4 = 6.9$				
p_w^{s*}	$14.80	$12.37	$7.90	$14.11
p_w^{r*}	70.00	12.37	70.00	70.00
p_s	14.80	12.37	7.90	14.11
p_r	3.50	0.62	3.50	3.50
% Buy	45	43	36	45
% Rent	4	48	13	4
Profit	5.9	4.7	2.6	5.6
% Change in C.S.		61.2	-56.6	-5.8
Panel 2: $\delta_r = \delta_s/10 = 2.76$				
p_w^{s*}	$14.80	$14.43	$7.90	$14.11
p_w^{r*}	28.60	14.43	28.60	28.60
p_s	14.80	14.43	7.90	14.11
p_r	1.43	0.72	1.43	1.43
% Buy	46	45	41	46
% Rent	2	29	7	2
Profit	5.9	5.8	2.5	5.6
% Change in C.S.		9.4	-57.4	-5.8

Table 6: 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 = 15):						
Month 1	39.4	0.2	2.6	44.7	7.7	23.4
Month 2	61.3	1.0	7.6	63.6	20.9	46.0
Month 3	76.8	11.7	15.3	75.1	37.9	66.6
Month 4	83.3	28.5	19.1	80.3	48.3	76.5
Month 5	88.0	42.9	29.7	84.8	56.7	83.1
Month 6	94.6	56.3	39.3	93.3	71.3	90.8
Month 7	100.0	68.0	52.4	100.0	84.2	94.5
Month 8	100.0	78.1	62.7	100.0	91.3	96.2
Months 9+	100.0	100.0	100.0	100.0	100.0	100.0
Panel 2: Sell-through Priced Titles (N = 31):						
Month 1	44.3	1.9	49.1	44.4	5.8	17.4
Month 2	66.1	15.3	58.4	64.3	20.6	34.3
Month 3	79.1	37.3	65.6	77.7	42.1	61.3
Month 4	85.3	52.5	71.2	83.7	55.6	74.8
Month 5	89.4	63.7	75.5	88.1	67.4	84.2
Month 6	95.3	75.0	84.1	94.7	79.3	91.3
Month 7	100.0	84.6	90.4	100.0	87.1	94.1
Month 8	100.0	92.9	94.1	100.0	93.4	96.4
Months 9+	100.0	100.0	100.0	100.0	100.0	100.0

Table 7: 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 = 15):						
Month 1	3.01	11.35	89.69	3.05	8.45	16.87
Month 2	3.02	7.91	76.06	3.18	9.09	16.48
Month 3	3.02	8.83	*60.42	3.29	8.33	16.53
Month 4	3.00	8.53	36.92	3.28	9.01	16.27
Month 5	3.02	8.78	12.59	3.23	9.24	15.60
Month 6	2.72	7.77	15.29	2.78	9.79	14.85
Month 7	2.72	6.90	11.32	2.78	9.92	14.90
Month 8	2.72	6.17	8.49	2.78	9.17	14.62
Months 9+	2.72	6.23	11.15	2.78	9.54	15.47
Panel 2: Sell-through Priced Titles (N = 31):						
Month 1	3.01	7.74	17.46	3.05	10.40	19.51
Month 2	3.17	7.69	16.62	3.62	11.35	17.08
Month 3	3.18	7.37	11.71	3.67	11.26	15.63
Month 4	3.15	7.07	13.42	3.85	10.96	15.49
Month 5	3.11	6.99	9.64	3.80	10.85	14.60
Month 6	2.74	6.48	10.78	3.09	9.89	13.23
Month 7	2.74	6.43	11.39	3.09	9.87	13.95
Month 8	2.74	6.30	10.15	3.09	9.49	12.53
Months 9+	2.74	5.99	10.45	3.09	9.87	11.63

*Uses Week 14 instead of week 13 average price, due to small number of observations in Week 13.

Table 8: Weighted Quantities of Rentals and Sales

	VHS			DVD		
	Rentals	Used Sales	New Sales	Rentals	Used Sales	New Sales
Panel 1: Rental Priced Titles (N = 15):						
Total per Title ('000)	1160.5	26.1	0.2	104.7	3.0	1.2
Weighted Total per Title	4231.0	73.0	248.5	397.2	8.3	109.3
Ratio, Weighted Sales/Rentals			7.6%			29.6%
Panel 2: Sell-through Priced Titles (N = 31):						
Total per Title ('000)	887.6	40.9	0.6	124.5	4.7	0.8
Weighted Total per Title	3236.0	114.6	392.7	472.4	13.2	140.8
Ratio, Weighted Sales/Rentals			15.7%			32.6%

Table 9: Estimated Parameter Values

| | VHS | | DVD (VHS was:) | |
	Rental Priced	Sell-through Priced	Rental Priced	Sell-through Priced
τ	24.64	16.93	18.96	18.16
μ_r	0.87	1.94	2.09	2.08
μ_u	6.03	7.54	10.11	11.26
μ_s (period 1)	33.14	4.76	1.14	1.76
μ_s (period 2)	3.28	–	–	–

Appendix A: Details

Estimation of the τ and μ is very straightforward. I use the technology equation to estimate τ. The format variable allows τ to differ for titles for which sell-through vs. rental pricing is used, due to the fact that the vertically-separated retailers face different cost structures under the two pricing arrangements. Thus, τ is estimated as:

$$E[(\tau - q_m/c_m) \cdot \text{format} \cdot \text{price type}] = 0$$

I assume that variation in τ is the result of measurement error, and not the result of strategic differences across stores in the intensity of their inventory use. The variance of measurement error for τ is estimated as:

$$E[((q_m/c_m)^2 - \tau^2 - \sigma_\tau^2) \cdot \text{format} \cdot \text{price type}] = 0$$

I estimate retailer markups as the difference between wholesale and retail prices, assuming that retailers receive a 40 percent discount off the suggested retail price of each videocassette tape or DVD. [24] Thus, for rentals, the markup is estimated as:

$$\mu_{r,m} = p_{r,m} - p_w^r \cdot (c_m/q_m)$$

For sales, the markup is:

$$\mu_{s,m} = p_{s,m} - p_w^s$$

The average μ's are simply estimated as:

$$E[(\mu_{r,m} - p_{r,m} + p_w^r \cdot (c_m/q_m)) \cdot \text{format} \cdot \text{price type}] = 0, \text{ and}$$

$$E[(\mu_{s,m} - p_{s,m} + p_w^s) \cdot \text{format} \cdot \text{price type}] = 0.$$

With variance σ_μ^2 estimated as:

$$E[((p_{r,m} - p_w^r \cdot (c_m/q_m))^2 - \mu_{r,m}^2 - \sigma_{\mu_r}^2) \cdot \text{format} \cdot \text{price type}] = 0 \text{for rentals, and}$$

$$E[((p_{s,m} - p_w^s)^2 - \mu_{s,m}^2 - \sigma_{\mu_s}^2) \cdot \text{format} \cdot \text{price type}] = 0 \text{for sales.}$$

Estimation of the quality and taste parameters proceeds by GMM, with an objective function given by

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

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). Estimation occurs separately for DVD and VHS formats, allowing all parameters to vary for the VHS and DVD populations.

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[24] 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 do not observe these, and assume that retailers pay the usual wholesale price.