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PRICE DISCRIMINATION, COPYRIGHT LAW, AND TECHNOLOGICAL INNOVATION: EVIDENCE FROM THE INTRODUCTION OF DVDS*

JULIE HOLLAND MORTIMER

U. S. copyright law effectively prevents direct price discrimination for copyright holders that sell to different markets. In response, these firms can engage in indirect price discrimination. I derive theoretical predictions about the use of indirect price discrimination, and I analyze how optimal pricing strategies differ for different products. Using data on VHS and DVD movie distribution, I find that firms' pricing choices are consistent with the predictions of theory and that firms' use of indirect price discrimination benefits consumers (but harms ancillary retailers). Finally, I examine what optimal pricing strategies might look like in a legal environment that permits direct price discrimination.

I. INTRODUCTION

The effects of intellectual property protection depend on how firms respond to the legal environment created by intellectual property laws. An important aspect of intellectual property law in the United States is a restriction that copyright law places on firms' abilities to directly price discriminate based on a consumer's intended use of a product. Firms may attempt to mitigate the effect of this restriction through legal indirect price discrimination.¹ To identify factors influencing firms' optimal pricing deci-

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1. Indirect price discrimination is also known as second-degree price discrimination or nonlinear pricing; buyers self-select across different prices from a menu (e.g., quantity discounts). Direct price discrimination is also known as third-degree price discrimination; buyers are assigned to different price offers by the seller based on their type (e.g., student discounts).

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sions under current U. S. copyright law, I empirically examine the outcomes of two pricing strategies (no price discrimination and indirect price discrimination) used by firms for products that are identical in content but distributed via an old established technology and a new emerging technology. The analysis uses a new dataset covering the distribution of movies on VHS and DVD formats to explain when different pricing strategies may be optimal, and to establish the welfare effects of price discrimination.

Under U. S. copyright law, copyright holders are granted the exclusive right to reproduce and sell their copyrighted good, as well as the right to control public displays of the good. Once the copyrighted good has been sold to a buyer, however, the copyright holder no longer has jurisdiction over subsequent (private) use of the product.² This restriction over subsequent use is commonly referred to as the "First Sale Doctrine" and applies to all copyright-protected products. This aspect of U. S. copyright law differs significantly from copyright law in other parts of the world, which usually grants explicit jurisdiction over subsequent uses, such as rentals. The First Sale Doctrine is commonly cited as providing the legal basis for such markets as video rentals, used sales of books and records, and resales of paintings.³ In the home video market, the First Sale Doctrine effectively strips movie studios of the ability to directly price discriminate between video stores and individual users because these buyers only differ in the extent of their subsequent use.

In the face of this legal restriction, copyright holders in the home video industry often use a form of indirect price discrimination. When releasing a movie on the VHS format, a firm initially sets a very high price for the videocassettes (around \$100), during which time the buyers are typically video rental stores purchasing rental inventory. Subsequently, the firm lowers the price substantially (to around \$20), at which time the typical buyers are end-users. This strategy is commonly referred to in the industry as "rental pricing" and has been used for the vast ma-

2. Specifically, U. S. copyright law is set forth in the U. S. Copyright Act of 1976. The restriction over subsequent use is the result of a 1984 Supreme Court case, *Universal vs. Sony*. Childs [1992] provides details of that case.

3. The First Sale Doctrine is distinct from the better known "Fair Use Doctrine," which allows duplication of copyrighted materials for the purpose of "fair" use (such as photocopying articles for personal use). It is still an open question as to how the First Sale Doctrine will be interpreted with respect to digital media where transferring ownership or allowing others to "rent" a legally-purchased copy generally requires duplication of the original.

majority of titles on the VHS format historically. For the remaining titles, the initial rental window is forgone in favor of generating early (and potentially more) 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. This practice, referred to as “sell-through pricing,” is typically used for children’s titles and occasionally for popular blockbuster titles or movies with teen-ager appeal. Examples of sell-through priced movies include *Antz*, *Titanic*, and *Blair Witch Project*.

With the introduction of the DVD format, studios have almost exclusively adopted sell-through pricing, 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 at least two possible explanations for this dramatic change in the pricing policy of the new format. On one hand, differences in the populations of consumers that adopt the DVD format in early years may lead to different optimal pricing choices. As late adopters enter the market, firms might again choose to adopt a rental pricing strategy to discriminate between the institutional and individual purchasers. On the other hand, the DVD format may be inherently different from the VHS format, allowing for convenient access to movies on laptop computers and additional viewing features. These new uses potentially affect the relative quality of owning and renting and may lead to different optimal pricing choices. In this case, one would expect that sell-through pricing will remain the standard for pricing in the DVD market.⁴ The goal of this paper is to understand what factors influence a studio’s choice of sell-through and rental pricing strategies and why the choice of pricing strategy may differ for the same movie on different formats. I also examine the welfare effects of price discrimination for firms and consumers in the context of different legal environments.

Estimation uses a structural model of consumer behavior in which different uses of a movie (e.g., owning and renting) are modeled as vertically differentiated products in a demand system. I use

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

a new dataset on weekly rentals and sales at over 2,000 video stores across the United States to estimate the demand parameters. The identification approach takes advantage of the large number of local markets in the dataset to allow for several free demand intercepts on each movie—one parameter for each use and format of each movie title. I instrument for rental price using a jackknifed estimate of a store's rental costs on other similar movies. The economic rationale for this strategy is that some stores use more inventory than others to satisfy a given level of demand, thus incurring higher costs. I find that the decision to price discriminate depends on the expected costs and benefits of doing so and that both demographic and technological differences matter for determining the new pricing of the DVD format. I also estimate that indirect price discrimination benefits copyright holders, and that consumer welfare is highest under the price discrimination strategies that are in use.

Other industries face similar challenges when pricing products. For example, book publishers price discriminate by sequentially releasing hardcover and paperback versions of a book. Markets for journal subscriptions, televised sporting events, live performances, and television shows all face similar challenges when pricing their products, and copyright holders in these markets employ a range of techniques to price discriminate among different types of consumers.

The paper proceeds as follows: Section II discusses related literature and describes the home video industry. In Section III, I describe the dataset and the timing of rentals and sales. Section IV lays out a demand system for rentals and purchases of a movie on a particular format and describes the firm's choice of whether or not to price discriminate. Section V modifies the demand system to incorporate institutional details, describes the estimation strategy, and discusses results. Finally, Section VI provides the results of welfare analyses.

II. RELATED LITERATURE AND THE HOME VIDEO INDUSTRY

II.A. Related Literature

A growing empirical literature addresses the topic of price discrimination, and a large literature addresses the theoretical implications of copyright provisions. However, to my knowledge, little empirical or theoretical literature addresses the implications of copyright law through its influence on price discrimina-

tion strategies or other static best responses in markets for copyrighted goods. A related previous study on price discrimination is Leslie [2004], which examines the welfare effects of both second- and third-degree price discrimination in Broadway theater.⁵ Others have empirically studied the effects of price discrimination in the presence of competition.⁶ Also related to this study, Clerides [2002] examines the implementation of intertemporal price discrimination in book sales, and Bergstrom [2001] examines institutional pricing of academic journals.⁷

In the home video industry, a strategy of no price discrimination can be more profitable than a strategy of indirect price discrimination because there is a cost to implementing indirect price discrimination (i.e., firms must reduce product quality by delaying the sell-through release to consumers). This is similar to treatments in the theoretical literature in which firms destroy quality to better sort consumers.⁸

The effects of intellectual property protection have been studied in other contexts, often focusing on the optimal theoretical level of copyright protection for the purpose of inducing investment in creative works,⁹ or the theoretical effects of piracy or unauthorized copying on firm profits and social welfare.¹⁰ The most closely related previous paper is Liebowitz [1986], which studies the impact of price discrimination by journal publishers on the working of copyright law. The treatment is primarily theoretical, although it reports some basic data on the prevalence of price discrimination in the market for academic journals and is based on work involving a Betamax court case. A much larger literature on intellectual property protection has focused on

5. Previous empirical work on price discrimination primarily tested whether or not different instances of price dispersion had a cost-based explanation or a price discrimination-based explanation. See Borenstein [1991], Shepard [1991], Borenstein and Rose [1994], among others. Leslie [2004] makes the point that in some cases we know that price dispersion is not cost-based. Thus, the question of interest is quantifying the welfare effects of price discrimination.

6. See McManus [2001], Miravete [2002], and Busse and Rysman [2005].

7. Direct price discrimination is used in the market for academic journals because libraries make the journals (and thus their content) publicly available. The "Fair Use Doctrine," which governs public display, gives firms jurisdiction over these uses and allows copyright holders to directly price discriminate on this basis. In contrast, the content of a movie cannot be publicly accessed by putting a VHS tape or DVD on a shelf—one must play the content privately at home.

8. Mussa and Rosen [1978] is a seminal contribution; Maskin and Riley [1984] extend their model, and Deneckere and McAfee [1996] also model damaged goods.

9. See Novos and Waldman [1984] and Yoon [2002].

10. See Ordoover and Willig [1978], Johnson [1985], Liebowitz [1985], and Takayama [1994 and 1997].

patent, rather than copyright, protection. An exception is McCalman [2004], which studies the governance structures and licensing behavior of movie studios across countries with different levels of intellectual property rights protection.¹¹ The role of purchase and rental markets to segment high- and low-value consumers has also been studied theoretically by Varian [2000], and an historical background of the video rental industry is provided in Roehl and Varian [2001]. Varian [2000] derives conditions under which pricing exclusively for a rental market, or pricing exclusively for direct sale, will be more profitable for the owner of an information good.¹²

II.B. Industry Background

In 1999, the \$16 billion home video industry accounted for 55 percent of studios' domestic revenues, compared to 22 percent generated by theatrical revenues and 23 percent from all other forms of media, such as the sales of pay-per-view, cable, and broadcast television rights.¹³ In the years since 1999, the home video industry has experienced several changes in composition, and the size of the industry has grown modestly. DVD revenue has displaced most VHS revenue, and based on the data and time period that I study (2000 and 2001), DVD revenue is comprised more heavily of sales than rentals (compared to the VHS format). Approximately 20,000 home video retail outlets, plus internet firms such as Netflix, maintain movie inventories for renting to consumers. The late 1990s witnessed some net consolidation of the retail industry, but this consolidation slowed by 2000, and the number of retail outlets is still close to 20,000 today.

Under indirect price discrimination (i.e., "rental pricing"), video retailers pay a wholesale price for each prerecorded videocassette tape of around \$60–\$70. After an initial period of rental activity (around five months), the distributor cuts the

11. Also related, McCalman [2001] studies the welfare effects of harmonizing patent protection across countries (via the TRIPs agreement of the Uruguay Round of GATT negotiations) by estimating a structural model of innovation using a modified version of the model in Eaton and Kortum [1996].

12. Varian 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, the choice becomes whether to price discriminate indirectly or not.

13. VSDA Annual Report, 1999.

TABLE I
INCIDENCE OF SELL-THROUGH PRICING, JANUARY 2000–DECEMBER 2001

Genre	% sell-through priced		Total released	
	A	B	A	B
Panel A: All A and B titles released on VHS				
Action/adventure	22.2	0.0	27	11
Children's/family	100.0	100.0	13	4
Comedy	29.4	2.7	34	37
Drama	15.8	0.0	19	24
Horror/suspense	0.0	0.0	17	15
Romance	0.0	0.0	4	5
Science-fiction	75.0	16.7	4	6
<i>Total</i>	<i>29.7</i>	<i>5.9</i>	<i>118</i>	<i>102</i>
Panel B: All A and B titles released on DVD				
Action/adventure	100.0	100.0	27	11
Children's/family	100.0	100.0	12	2
Comedy	100.0	100.0	27	37
Drama	100.0	96.0	19	25
Horror/suspense	100.0	100.0	13	16
Romance	100.0	100.0	4	5
Science-fiction	100.0	100.0	4	7
<i>Total</i>	<i>100.0</i>	<i>99.0</i>	<i>106</i>	<i>103</i>

Tabulations compiled by author using data from Rentrak Corporation on all "A" and "B" titles released between January 2000 and December 2001. "A" titles grossed at least \$40 million in theatrical revenues. "B" titles grossed \$15–40 million in theatrical revenues.

wholesale price from \$60–\$70 to \$10–\$15, called "sell-through repricing." At this time the movie is commonly sold to individual users. This two-tiered pricing strategy is a form of indirect price discrimination and helps to distinguish between individuals and institutional buyers (i.e., video stores). Exceptions to this pricing pattern are titles priced for "sell-through." In this case, indirect price discrimination is discarded in favor of an immediate \$10–\$15 wholesale price to stimulate early sales to individual users.

Table I details the use of sell-through pricing for the VHS and DVD formats. These figures are compiled from the dataset described in the next section and include all major titles released between January 2000 and December 2001. Titles are classified as "B" or "A" if they earned \$15–40 million or more than \$40 million, respectively, in theatrical box-office revenue. The incidence of sell-through pricing for all titles released on VHS (shown

in Panel A) is around 19 percent. Children's and family movies are always sell-through priced, while romance, suspense, and drama titles are almost never sell-through priced in the dataset. Science fiction titles are likely to be sell-through priced if the title has a large theatrical box-office. In contrast to this, Panel B shows the use of sell-through pricing for the same movies under the DVD format. With the exception of a single B title in the drama genre, all titles are sell-through priced.

III. DATA

III.A. Primary Data Sources

The primary dataset used for this study is a new dataset of DVD and VHS rental and sales transactions at video retail stores provided by Rentrak Corporation.¹⁴ The dataset contains transactions at 4,341 stores from January 2000 through June 2002. I eliminate 2,128 stores that did not carry most major titles because they exited the database at an early date or entered the database at a late date. This leaves 2,213 video retail stores. For all stores, I observe the zip code location.

The stores in Rentrak's database are video specialty retailers, but rentals and purchases can be made at other retail outlets. As I detail in the Data Appendix, about three-quarters of all VHS and DVD rentals occur at video retail outlets, but a greater proportion of sales occur through alternative distribution channels. I use auxiliary phone-survey data on purchases at all outlets to weight the sample of video retailers appropriately.

For each title released on video between January 2000 and December 2001, I observe theatrical box-office revenues, genre, and MPAA rating. I do not observe title names. I focus on titles with theatrical box office revenues of at least \$55 million to ensure sufficient coverage of the sales market. I track the rental and sales activities of each title for at least six months on both formats. Finally, I limit my attention to titles that are not available on revenue-sharing contracts. Revenue-sharing contracts allow retailers to pay a very low per-tape fee (between \$3 and \$8)

14. Over 10,000 retailers used Rentrak to process data 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. Blockbuster Video does not release their data, and Hollywood Video recently settled a lawsuit with Rentrak involving a dispute over data integrity.

in exchange for sharing rental revenue with the movie studio. I drop these titles because they are never considered for sell-through pricing and because the payment structure that applies to retailers is much more complex than the simple linear prices considered here.¹⁵ This leaves forty-one major titles in the analysis. An observation is a store-title pair, which is constructed after summarizing weekly transactions data.

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 2000 through 2002. From these data, I identify the total number of video retail stores within the same zip code of each observed store in the Rentrak database. In addition, I utilize data from the 2000 U. S. Census on the demographic characteristics of each zip code. Demographic data include the number of people, median income, and marginal distributions of race, education, age, gender, employment, family status, and the level of urbanization in each zip code. These three data sources (phone book listings, demographics, and transactions data) are merged by zip code.

To specify the portion of consumers that are active in a market for either the DVD or VHS format, I use data on monthly DVD hardware penetration rates for each state. I assume that after a household has purchased a DVD player, they rent and purchase newly released titles on the DVD format.¹⁶

Finally, there is substantial variation in the price paid by consumers, both across stores and across titles within a store.¹⁷ In addition to rental activity, most stores sell used tapes for the forty-one titles in the analysis and charge different prices. However, some stores have zero market share for new sales of a title.¹⁸

15. Approximately half of the major studios offer revenue-sharing contracts at this time. Although I do not observe title or studio names, I do observe that many of the included 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.

16. I thank Pinar Karaca-Mandic for her help in acquiring these data, and Centris for providing them. I provide additional detail on these in the Data Appendix.

17. I focus on the average price of a store-title pair. Thus, variation across titles within a store comes from having different prices for different titles at any point in time as well as from variation in how quickly a title is moved from a high-price "New Release" section to a low-price "Catalog" section. Price variation across stores is more extensive than variation within-store. See Mortimer [forthcoming] for more detail on price variation for a similar dataset.

18. An additional motivation for selecting titles with at least \$55 million in theatrical box-office receipts is that there is broad coverage of the titles across many stores. This is especially important for shares of new sales, which are underrepresented in my dataset.

TABLE II
TIMING OF RENTALS AND SALES: CUMULATIVE PERCENTAGES BY MONTH

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

Tabulations compiled by author using data from Rentrak Corporation for the forty-one titles used in the analysis, which are released between January 2000 and December 2001. "Month" denotes the number of months since a title's release on VHS/DVD. (All included titles are released simultaneously on both formats.)

When I observe a zero market share for new sales, I assume the local price is equal to the suggested retail price (SRP), with the exception that rental priced VHS titles are assigned the wholesale price faced by a retailer before re-pricing, and they are assigned the repriced SRP after repricing.

III.B. Timing of Rentals and Sales

Table II provides summary statistics from the data on both the quantity and timing of rentals and sales. For the forty-one titles used in the analysis, I compute weekly totals of rentals and sales for each title based on the first week it appeared at a store. Panel A refers to titles with a rental priced VHS release, and Panel B refers to 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 forty-one titles, twelve are rental priced (in the top half) and twenty-nine are sell-through priced. 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.

Columns (1) and (4) provide information on the timing of rentals for VHS and DVD. Approximately two-thirds of all rentals occur during the first two months for both sets of titles and formats and at least 85 percent of all rentals occur in the first five months. Columns (2) and (5) examine used sales. Relatively few used sales occur during the first two months when the rental market is most active; however, by month five, roughly half of all used sales have occurred. Unlike rentals and new sales, the sales of used tapes are not as clearly delineated by the timing of purchases, which is similar across the four quadrants of Table II. Finally, columns (3) and (6) examine the timing of new sales. For rental priced VHS titles, relatively few sales of new tapes (less than 15 percent) occur during the first five months. In contrast, roughly three-fourths of all new sales take place in the first five months for sell-through priced VHS titles, and this figure is nearly 85 percent for DVD titles.

Nominal monthly prices of rentals and sales are shown in Table III. Rentals of DVDs are slightly more expensive than VHS; there are no significant differences in the price of a rental according to whether or not a film was rental priced. This is somewhat surprising: one might expect that lower costs of inventory should yield lower rental prices to consumers. I say more about this in the discussion of retailer behavior later in the paper. Prices of rentals do not change after month 5, because I aggregate rental transactions that occur after week 21 and report the average price. Prices of used sales are slightly higher for DVDs, and there are no significant differences between prices of used tapes based on whether or not rental pricing was used. Prices of used tapes are fairly constant over time. Average prices of new tapes during the first five months (before sell-through repricing occurs) range from \$89 to \$100. In contrast, prices of new sales in months 6 and higher average between \$18 and \$27. For sell-through priced VHS and all DVDs, prices of new sales after month 5 are very similar to prices in the first five months, although there is a small reduction in price over time.

TABLE III
MONTHLY AVERAGE PRICES OF RENTALS AND SALES

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

Tabulations compiled by author using data from Rentrak Corporation for the forty-one titles used in the analysis, which are released between January 2000 and December 2001. "Month" denotes the number of months since a title's release on VHS/DVD. (All included titles are released simultaneously on both formats.) All prices are nominal.

IV. MODEL

In this section, I outline a model of consumer demand and firm behavior restricted by current copyright law that specifies the conditions under which indirect price discrimination is a more profitable pricing strategy than nondiscriminatory pricing. I also compare these outcomes to the results under an alternative copyright law where firms are able to use direct price discrimination. The model consists of a demand system for consumers and a supply decision for the firm. Consumers consider a single product that is vertically differentiated according to whether or not the product is rented or purchased, and the supply decision specifies the firm's profit function and examines the conditions that determine the optimal pricing strategy. Throughout the model, I ig-

nore any active role for retailers or variation in local retail market structure and focus solely on the decisions taken by the movie studio (i.e., “the firm”). I bring these issues back into my welfare calculations at the end by examining retailer markups, which are recorded in the data. The goal in this section is to provide intuition in the simplest setting; the goal in the empirical work to follow is to be as general as possible in specifying the problem.

IV.A. *Consumer Demand*

Consider a standard model of consumer demand for two vertically differentiated products, the rental or purchase of a given movie title on a particular format.¹⁹ For each title, I assume that the firm has monopoly ownership.²⁰ Consumers’ utility functions are specified by

$$(1) \quad u_i = \begin{cases} \delta_{i,s} - \alpha_i p_s & \text{if purchase,} \\ \delta_{i,r} - \alpha_i p_r & \text{if rent,} \\ 0 & \text{otherwise.} \end{cases}$$

The parameters $\delta_{i,s}$ and $\delta_{i,r}$ represent the quality to consumer i of purchasing and renting, respectively; p_s and p_r denote the prices for purchasing and renting. The parameter α_i represents the consumer’s marginal utility of income and differs across individuals according to their income level and their unobservable willingness to pay for movie quality. Note that the inclusion of unobservable differences in α_i can accommodate differences in a consumer’s opportunity cost of time or any other factor that affects willingness to pay for movie quality. The quality parameters can be interpreted quite generally. For example, suppose that quality differs across consumer characteristics, so that

$$(2) \quad \begin{aligned} \delta_{i,s} &= \delta_s + X_i\beta, \text{ and} \\ \delta_{i,r} &= \delta_r + X_i\beta. \end{aligned}$$

There is an average value of owning or renting given by δ_s and δ_r . Beyond that, consumers differ in their utility from owning or

19. Bresnahan [1987] used a vertically differentiated model to analyze the automobile industry; Song [2004] is a more recent example in which a vertically differentiated model is estimated. Much of the notation used here follows that in Berry [1994].

20. Studios attempt to avoid competing with each others’ titles by choosing different release dates: the forty-one titles analyzed here are released across 108 weeks to avoid direct competition between titles. The inclusion of competing titles, although a potentially attractive extension of the model, requires an alternative set of assumptions about the nature of competition over time as new movies are released.

renting a movie if they differ in X_i . X_i could include the number of times a consumer has already seen the movie, her family status, where she lives, and so on.²¹ Utility maximization implies that consumers for whom $\alpha_i < (\delta_r - \delta_s)/(p_r - p_s)$ will purchase, those for whom $\alpha_i > \delta_{i,r}/p_r$ will choose the outside good, and the remaining consumers will rent.

IV.B. The Pricing Decision

The movie studio maximizes

$$\max_{\{p_r^w, p_s^w\}} \pi = N[(F(\hat{\alpha}) \cdot (p_s^w - c) + (F(\hat{\alpha}) - F(\tilde{\alpha})) \cdot (p_r^w/\tau - c/\tau)]$$

where $\tilde{\alpha} = (\delta_r - \delta_s)/(p_r - p_s)$ and $\hat{\alpha} = \delta_{i,r}/p_r$, and N denotes the number of consumers. The parameter c denotes production cost, and p_s^w and p_r^w represent wholesale price in the sales and rental market, respectively. The cumulative distribution function of the underlying consumer preferences α_i is denoted by $F(\cdot)$. Assuming perfect competition in the retail sector and no additional costs, $p_s = p_s^w$. The presence of retailer markups or costs (denoted μ_s) would lead to $p_s = p_s^w + \mu_s$. The price of renting a tape is specified as $p_r = p_r^w/\tau$, which also assumes no retailer costs or markups, and allows for each tape or DVD to rent out a fixed number of times τ . This accounts for the fact that multiple rentals may be produced from each copy of the movie. The addition of retailer markups or costs would lead to $p_r = p_r^w/\tau + \mu_r$.

The presence of τ introduces some complications into the model. Specifically, one worries that retailers have control over how intensively they use inventory and can influence τ . In fact, one expects that retailers' decisions will depend on how the movie is priced, with more intensive use made of higher-priced tapes. When considering the pricing decision of the firm, I assume that τ is fixed and known to the firm. However, I allow it to differ according to how tapes are priced to address differences in retailer behavior.²² The presence of τ also leads to the possibility that rentals are rationed in any particular week. This is an

21. Note that unobserved consumer characteristics are contained in α_i and their inclusion in the $\delta_{i,e}$'s is not separately identified (i.e., whether you receive lower unobserved quality from the good or just have a lower willingness to pay for it is indistinguishable).

22. I assume that there are limits to how intensively retailers can use a tape or DVD. Specifically, I rule out the possibility that a retailer can buy one tape to serve any level of rental demand. Technically, this requires an additional constraint, which is that realized sales are given by $\min(F(\hat{\alpha}) - F(\tilde{\alpha}), \tau \cdot \text{Inventory})$.

important reason for aggregating rentals over time, because consumers can return over a period of several months to rent the movie later if it is stocked out at any particular time.²³ More generally, retailer behavior (whether through inventory usage τ , or the addition of markups or costs) is important for conducting counterfactual experiments on the firm's pricing decision, and I return to a more extensive discussion of retailer variables (including τ and the markups μ_r and μ_s) in the section on counterfactual policy experiments.²⁴

Under direct price discrimination, the firm sets different prices in the rental and sales markets simultaneously. All rental stores pay p_r^w , all consumers pay p_s^w , and rental consumers pay p_r^w/τ for a rental. This strategy is not feasible under current U. S. copyright law because firms are not allowed to charge different prices for different uses of the product.

In the absence of price discrimination, the firm sets a single wholesale price p^w . The relative price of a sale compared to a rental is no longer under the control of the firm because the sales price is always larger by a factor of τ . While the no-price-discrimination strategy is consistent with U. S. copyright law and used for virtually all movies released on the DVD format, the restriction of only being able to set a single price can be costly to the firm.

In the absence of direct price discrimination, it may be possible to discriminate indirectly. In the home video industry, firms do this by lowering price about five months after a title's initial video release. In principle, firms could adjust price at many points in time. In practice, however, firms in this industry consistently chose a single repricing date. Consequently, I assume that firms are able to commit to future price paths, and I focus on firms' decisions to either price discriminate over two periods or not price discriminate at all.

Suppose that the value of the good to consumers decays between the two periods so that the value of purchasing in the later period is $\delta_{s2} < \delta_s$. This captures the erosion of word-of-mouth, movie reviews, theatrical advertising, the disutility of waiting, or other factors that influence the quality of purchasing

23. For additional robustness tests of alternative modeling choices for the τ variable in the context of revenue-sharing programs, see Mortimer [forthcoming].

24. Estimation uses demand-side conditions only. Thus, none of the supply conditions discussed here affect the estimation of the quality parameters. They do, however, impact the results of the counterfactual estimates.

a movie over time.²⁵ Also, I assume that the rental market is fully served in period one (i.e., there are no “second-run” video stores that delay purchasing titles until they have been repriced).

The use of indirect price discrimination introduces a third product into the choice set so that consumers maximize utility over

$$(3) \quad u_i = \begin{cases} \delta_{i,s} - \alpha_i p_s & \text{if purchased in period 1,} \\ \delta_{i,s2} - \alpha_i p_{s2} & \text{if purchased in period 2,} \\ \delta_{i,r} - \alpha_i p_r & \text{if rented in period 1, and} \\ 0 & \text{otherwise,} \end{cases}$$

where p_{s2} is the price of purchasing in period 2. The firm has more control over the relative prices of rentals and sales compared to no price discrimination, but they destroy value to sort consumers because $\delta_{s2} < \delta_s$.²⁶

Conditional on the rental technology τ , the decision to use indirect price discrimination or no price discrimination should depend upon (1) the value of the good in the rental market compared to its value in the sales market and (2) the decay rate of the quality of owning between the first and second periods. Specifically, theory gives two predictions.

PREDICTION 1. All else equal, indirect price discrimination becomes relatively more attractive as the value of the good in the rental market increases (i.e., as $\tau \cdot \delta_r$ rises).

Intuition. There is a stronger incentive to price discriminate between institutional and individual buyers as the total value of the good in the rental market increases. In this case, institutional buyers are willing to pay more for their rental inventories, so the benefit of discriminating across types of buyers is higher. Conversely, if the value in the rental market is relatively low, the firm is more likely to forgo indirect price discrimination and sell directly to consumers in the first period. This could happen if, for

25. The quality decay differs from a discount factor because it does not apply to price or cost. A more critical assumption is that firms do not choose the extent of decay (for example, by engaging in special sales-oriented advertising campaigns or other initiatives). It is difficult to identify such effects empirically, and I have no reason to believe that the “choice” of quality decay is a first-order decision for the firm in this context.

26. In the absence of direct price discrimination, non-discriminatory pricing is preferred to indirect price discrimination whenever the optimal second-period price exceeds the optimal first-period price because consumers cannot be prevented from purchasing in the first period and will indeed choose to do so.

example, consumers want to watch the movie many times (such as for children's titles).

PREDICTION 2. All else equal, indirect price discrimination becomes relatively more attractive as the decay rate falls (i.e., as δ_{s2} rises).

Intuition. The cost to the firm of delaying sales falls with the decay rate. Thus, a higher δ_{s2} makes indirect price discrimination more attractive. Several factors could result in a higher δ_{s2} for one movie versus another: consumers of the movie may be relatively patient, or characteristics of the movie (i.e., "timeless" appeal) may lead to a slower rate of quality decay.

Both predictions have strong intuition. However, to provide an example of the firm's pricing decision and show that Predictions 1 and 2 hold, one must make assumptions about distributions and parameter values and numerically simulate the pricing decision. I have explored a range of reasonable assumptions through numerical simulation and have generally found support for both predictions. For example, assuming that α has a Weibull distribution with parameters ($\lambda = 6$, $\rho = 1$), retailer markups are zero (i.e., $\mu_r = \mu_s = 0$), $N = 1$, $c = 2$, $\tau = 30$, $X_i\beta = 0$ for all i , and $\delta_s = 2$, I solve for the optimal pricing strategy over a range of values for $\tau \cdot \delta_r$ (from 5 to 6.67 times δ_s) and δ_{s2} (from 0.45 to 0.60 of the value of δ_s). The results support both predictions.

V. ESTIMATION AND RESULTS

In this section, I describe the necessary extensions of the demand specification, distributional assumptions, and sources of identification that are used in estimation. I use only demand-side moment restrictions for the purpose of estimation; supply-side restrictions are not used for estimating the parameters of the demand system. After confirming a reasonable fit of the model's parameters, I incorporate supply-side information and provide additional modeling of the retail sector for estimating welfare effects in the counterfactual exercises.

V.A. Estimation and Identification

In the data, I observe one additional option chosen by consumers: purchase of a used tape (or DVD). Thus, to estimate demand, I must include the purchase of a used tape or DVD as an

additional product. I assume a used tape provides lower quality than a new tape, but higher quality than a rental (for a particular title and format). Markets are defined as a zip code title format triple as described in the Data Appendix. I consider two time periods for rental priced titles: before and after sell-through repricing. Thus, a market includes three (or four) products: the rental of a title, the purchase of a used tape, and the purchase of a new tape (both now and—if rental priced—later). Consumers in a particular zip code choose among these products for either the VHS or DVD format, depending on which hardware they own.

I specify a Weibull distribution for the parameter α , which captures the marginal utility of income. The Weibull distribution has parameters (λ, ρ) , such that $\lambda, \rho > 0$, and λ is specified as $\exp(Z'_m \gamma)$, where Z_m contains a constant term and the log of median income. Plugging in the functional form of the Weibull distribution gives the predicted demand for rentals:

$$(4) \quad q_{r,m,j} = N \cdot \left(\exp \left(-\exp(Z_m \gamma) \left(\frac{\delta_{u,m,j} - \delta_{r,m,j}}{p_{u,m,j} - p_{r,m,j}} \right)^\rho \right) + \exp \left(-\exp(Z_m \gamma) \left(\frac{\delta_{r,m,j}}{p_{r,m,j}} \right)^\rho \right) \right),$$

where the definition of market size, N , is defined appropriately according to the Data Appendix. The subscript u denotes purchase of a used tape or DVD. Similar solutions apply for new and used sales. The subscripts denote variation across use, titles, and geographic market areas. Thus, $\delta_{r,m,j}$ represents the quality level of a rental (r) of title j in market m . Furthermore, all quality levels take a different value for each format. Solving recursively across all uses of the good, I can rewrite the demand expressions in terms of the quality parameters. The quality of renting, for example, is given by

$$(5) \quad \delta_{r,m,j} = p_{r,m,j} [-\ln(s_{0,m,j}) \cdot \exp(-Z_m \gamma)]^{-(1/\rho)},$$

where $s_{0,m,j}$ denotes the market share of the outside good. In general, local market shares for the different uses of a title format are denoted by $s_{\cdot,m,j}$, etc., and are defined as $q_{\cdot,m,j}/N$. Similar expressions are solved recursively for the local quality of used and new purchases ($\delta_{u,m,j}$, $\delta_{s2,m,j}$, and $\delta_{s,m,j}$). The quality of a used tape acts as a baseline category for the utility comparisons across the other choices, and provides a lower-bound to second-period sales quality when second-period sales are not observed.

I decompose the market-specific quality of a rental as

$$(6) \quad \delta_{r,m,j} = \delta_{r,j} + X_m \beta_j + \xi_{r,m,j}.$$

The quality of used and new sales are similarly defined. The term $\delta_{r,j}$ denotes the national average quality of a rental of movie j . Note that for each movie, there are up to seven free demand parameters: one each for the national average value of rental, used, and new purchases (both now and—for rental priced titles—later) for each of the two formats (DVD and VHS). The ability to include so many free parameters comes from the large number of markets and is an attractive feature for estimating demand when many of a product's important attributes, such as the quality of a star's acting, may be unobservable.

The effects of any observable X_m (i.e., the β_j 's) are allowed to differ across both titles and formats, but not across different uses. This allows for horizontal differentiation across geographic markets for different movie titles on the basis of observables. For example, movie j may be more valuable on the DVD format in market m because it appeals to the demographic characteristics of the local DVD population. Local demographic shifters (X_m) include the percent of the area that is suburban, store size, the percent of families who are married with kids, and the local DVD penetration rate, which is measured at the state level in each month. The inclusion of the DVD penetration rate is intended to proxy for demographic effects that are otherwise difficult to capture. For example, DVD adoption happens earliest at both high and low income levels but varies significantly across geographic areas. Finally, $\xi_{r,m,j}$ captures the unobserved quality of a use of title j in market m . For example, a rental of title j may be more valuable in market m because of unobservable promotions or community events.

As usual, one may worry that the unobserved attributes $\xi_{r,m,j}$ may be correlated with the local retail price, $p_{r,m,j}$, and any such correlation will bias the estimate of γ . A valid instrument for price must be uncorrelated with the unobserved attributes of the good, but still correlated with price. Thus, researchers often use an instrumental variable that is either correlated with costs, or correlated with competitive conditions from the supply side. These measures affect price but are uncorrelated with tastes for unobserved features of the product. In this case, one would like to instrument for all three uses of the good: rentals, used sales, and new sales. However, a cost of the unrestrictive specification of the

δ parameters is that the only price variation not collinear with the demand intercepts is variation across stores for the same movie in the same format and use. Thus, the instruments must vary across store-title pairs.

One might be tempted to think that a store's variable cost of a rental (for a given title and format) is a good instrument for rental price. This cost may be calculated in the data by dividing the wholesale price of a tape by the number of rentals per tape for that store-title pair, where the wholesale price assumes a 40 percent discount off the observed suggested retail price of each videocassette tape or DVD.²⁷ Variation in retailers' average costs of rentals (for a given title and format) thus arises because of variation in the number of rentals per tape for a title: some retailers purchase ten tapes and produce 100 rentals from them, while others purchase ten tapes and produce 200 rentals from them. Unfortunately, constructing this variable requires an ex post measure of rental demand (through division by the quantity of rentals) and so, by construction, the instrument is correlated with tastes for unobserved attributes of the local rental use of that title and are thus invalid.

Alternatively, one can construct an *expected* average cost of a rental of a title at a store by essentially jackknifing the cost of other similarly priced titles on the same format, where "similarly priced" refers to rental or sell-through pricing. For example, of the twelve titles released under rental-pricing terms on the VHS format, the *expected* average cost of a rental of title 12 at store k is measured by the average cost of a rental of titles 1–11 at store k . The *expected* average cost for title 1 may be constructed in a similar fashion, averaging over titles 2–12, etc. This measure captures common cost components that store k faces for rental priced titles on the VHS format, but preserves the title-level variation within the store. Essentially, the instrument captures the retail store's strategy: high rationing (low quality) or low rationing (high quality), which is correlated with the price of the rental but not with unobserved quality of the title.

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

Although the use of this “jackknife” strategy addresses the issue of correlation with a title’s own demand that arises from using actual costs, it still faces important limitations. Principally, the assumptions needed for validity of this instrument are quite strong. To be valid, variation in this instrument must be driven only by cost factors and not by features of local demand that stores take into account when choosing an inventory policy. For example, if variation in this instrument is due to retailers’ impatience in servicing demand, the instrument is valid. This could happen if the costs of shelf space for new releases are higher at one store than another (e.g., a store holds a larger stock of older catalog titles). Similarly, if variation in rental turns per tape is due to differences in management skill or employee organization (e.g., tapes get lost or broken more often at one store than another), the instrument is also valid. However, if differences in consumer impatience or other features of demand lead a retailer to stock higher inventory levels in a store, the instrument is no longer valid. Although cost-side effects do exist, it seems likely that demand-side effects also happen in reality, which is problematic for my instrumental variable strategy. Unfortunately, I have been unable to identify a better instrument that still allows for the unrestrictive specification of the quality parameters. The direction of the bias if the instrument is compromised by demand-side effects is that movies with unobservably better quality are in higher demand, and these store-title pairs also display a higher price. This leads to an upward bias on the mean price coefficient, γ_0 .

A second alternative would be to not instrument for rental price. One might argue that there is sufficient stickiness in price across titles at a retail location, and that instrumenting for price is not necessary. In the analysis that follows, I present results with the instrument for rental price, but not instrumenting yields results that are qualitatively the same.²⁸

For used sales, one might consider using the total rental inventory that the retailer ordered for a title, less one unit. This is, by definition, his available supply of the used product. However, one may worry that $\xi_{u,j,m}$ need not be uncorrelated with $\xi_{r,j,m}$, and if they are correlated, the inventory of the title is not

28. The similarity between the OLS and IV results could result from price stickiness (in which case there is not much need to instrument for price), or from the fact that the instruments used are compromised by demand-side effects.

a valid instrument. Instead, I construct a second “jackknifed” instrument using the *expected* average inventory of other similar titles to instrument for the price in the used market.²⁹

Instrumenting for new sales is more straightforward. The cost to the retailer of a title depends only on the wholesale price. Unfortunately, this does not vary across retailers. Therefore, I interact the wholesale price paid by retailers with their observed competitive conditions, which includes the number of video stores in the same zip code.³⁰ This instrument captures both cost factors and market conditions and preserves variation across stores for a given title.

One can now combine (5) and (6) to form moment conditions:

$$(7) \quad E(W' \xi_{.m,j}) = 0$$

where W includes Z_m and the instrumental variables. The parameters to be estimated are $\theta \equiv (\delta_r, \delta_u, \delta_s, \delta_{s2}, \beta, \gamma)$. The parameters δ_r , δ_u , and δ_s are all vectors of length J (the number of titles), while δ_{s2} has length equal to the number of rental priced titles. Estimation proceeds using generalized method of moments, choosing θ to minimize

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

where $\psi(\theta, W_i)$ is the set of moment conditions, i is now used to denote format-title-use observations, and A is a weight matrix chosen to minimize variance according to Hansen [1982].

Direct estimation of $\hat{\theta}$ is difficult because of the large number of demand parameters (258 parameters in the δ vectors, plus 328 parameters in the β vector, plus three parameters in the γ and ρ vectors). However, all of the δ and β parameters enter ξ linearly, which allows me to simplify the estimation by using a two-step procedure. I first guess values for the δ and β vectors, then given those values, I minimize the objective function (which is nonlinear) over values of γ and ρ . Given the new values of γ and ρ , I construct fitted values of $\delta_{.m,j}$'s, which I then regress on title-

29. This instrument is constructed analogously to the *expected* average cost in the rental market, using inventory, not average cost.

30. Note that the wholesale price set by the studio only depends on the national average quality, not local deviations from that. So any unobserved quality that is accounted for in the wholesale price is picked up by the demand intercepts $\delta_{s,j}$.

use-format dummies and the X_m 's to recover new estimates of the δ and β vectors. I iterate this procedure until convergence.

As utility functions are ordinal, I need to normalize at least one of the quality parameters. I normalize the value of the outside good for movie 1 on the VHS format such that $E(X_m\beta_1)$ is equal to a constant.³¹ The remaining δ parameters are identified from market shares both in levels and in relative terms. Specifically, better movies overall have higher market share for all uses, and movies with higher market share in the sales market relative to the rental market have a higher sales value. Market shares vary across movies, formats, and retail store locations for a given price. The γ and ρ parameters are identified from (1) the normalization of the quality of the first movie in the first market, (2) variation in income, and (3) variation across geographic markets in the relative market shares of rentals versus sales (for all movies).

V.B. Estimation Results

Table IV provides estimation results. Panel A reports estimates of the parameters of the model. Rather than report forty-one sets of quality parameters (one set for each title), I report means of the parameter estimates and standard errors for each of the four format-pricing types (i.e., VHS and DVD formats based on whether the VHS format was rental priced or sell-through priced). After discussing the means, I provide scatterplots comparing the quality parameters for individual movies.

The parameters of the distribution of α indicate that neighborhoods with higher median income are associated with a higher willingness to pay for movies on tape or DVD ($\gamma_1 = 0.96$). The β parameters affect the "local quality" or local taste for movies, across all uses of a title. Larger stores are located in neighborhoods with greater demand for movies regardless of format. (The average β associated with store size is positive.) A higher proportion of "married with children" households is associated with a lower demand on the VHS format but with a higher demand on

31. I calculate the value of $E(X_m\beta_1)$ by setting $\alpha = 1$, computing the $\delta_{\cdot,m,j}$'s and then regressing $\delta_{\cdot,m,j}$ on use dummies and X_m . The vector β_1 from this regression (i.e., the value of the β vector for title 1 on VHS) was then used to normalize the outside good in each market for title 1. This was done to preserve geographic variation in the normalization for title 1. Normalizing the value of β_1 to be zero in all geographic markets would be perfectly valid from an econometric point of view but would give the same value of the outside good for all geographic markets. My method normalizes β_1 to be equal to a vector of nonzero constants while preserving variation across markets.

TABLE IV
ESTIMATION RESULTS

	VHS		DVD (VHS was:)	
	Rental priced	Sell-through priced	Rental priced	Sell-through priced
Panel A: Estimated parameter values				
Parameters of the distribution of α^a :				
Constant (γ_0)		-0.786 (0.054)		
Median income (γ_1)		0.958 (0.046)		
Shape parameter (ρ)		1.814 (0.008)		
Average taste parameters (β_j 's):				
Store size	0.244 (0.011)	0.210 (0.009)	0.372 (0.016)	0.293 (0.012)
% married/kids	-1.121 (0.333)	-0.975 (0.267)	0.879 (0.435)	0.814 (0.354)
% suburban	0.075 (0.137)	0.249 (0.109)	-0.304 (0.176)	-0.198 (0.143)
% DVD penetration	3.764 (1.037)	1.650 (0.936)	-10.492 (1.646)	-3.514 (1.199)
$E[X\beta]$	1.221	0.881	0.962	1.150
Average national quality parameters ($\delta_{.,j}$'s) ^b :				
Rental quality ($\delta_{r,j}$)	0.062 (0.142)	0.348 (0.112)	0.304 (0.184)	-0.044 (0.151)
Used quality ($\delta_{u,j}$)	0.261 (0.142)	0.621 (0.112)	1.016 (0.184)	0.388 (0.151)
Second period quality ($\delta_{s2,j}$)	0.379 (0.142)	—	—	—
First period quality ($\delta_{s,j}$)	0.581 (0.142)	0.819 (0.112)	1.595 (0.184)	0.639 (0.151)
Panel B: Average predicted quality estimates ($\delta_{.,m,j} = \delta_{.,j} + X_m\beta_j$)				
$E(\delta_{r,m,j})$	1.293	1.209	1.267	1.118
$E(\delta_{u,m,j})$	1.491	1.481	1.989	1.568
$E(\delta_{s2,m,j})$	1.605	—	—	—
$E(\delta_{s,m,j})$	1.802	1.679	2.588	1.831
$E(\delta_{s2,m,j})/E(\delta_{s,m,j})$	0.891	—	—	—
$E(\delta_{r,m,j})/E(\delta_{s,m,j})$	0.718	0.720	0.490	0.611

the DVD format although this varies by movie and genre. Suburban areas have relatively lower demand for the DVD format compared to their nonsuburban counterparts. This effect is often not statistically significantly different from zero for individual titles. DVD hardware penetration rates are strongly correlated

TABLE IV
(CONTINUED)

	VHS		DVD (VHS was:)	
	Rental priced	Sell-through priced	Rental priced	Sell-through priced
Panel C: Averages of retail parameters used in counterfactuals				
Inventory use (τ)	23.74 (13.72)	16.91 (8.37)	15.60 (10.66)	15.31 (10.40)
Rental markup (μ_r)	-0.03 (2.09)	1.88 (0.80)	0.90 (2.52)	0.38 (3.57)
Used sale markup (μ_u)	8.45 (1.95)	7.71 (1.57)	10.29 (1.53)	11.57 (2.17)
Sale markup, period 1 (μ_{s1})	43.60 (1.74)	9.50 (5.76)	8.19 (4.13)	10.61 (3.17)
Sale markup, period 2 (μ_{s2})	4.09 (2.33)	—	—	—
Local Mkt. Size (000s)	5.62 (3.46)	5.49 (3.41)	0.69 (0.60)	0.79 (0.67)
No. Obs.	23,213	58,077	18,041	42,118

Standard errors reported in Panel A; standard deviations reported in Panel C. Standard errors are corrected for within-title and within-store correlation where appropriate (i.e., γ and ρ).
 a. Parameters of the distribution of α are restricted to be constant across titles.
 b. The standard errors on the four usage types are equal because the sum of the squared usage dummies is the same for all four types (i.e., each usage type has an observation for each title at each store).

with tastes for movie watching. Neighborhoods with higher DVD penetration are estimated to have lower demand for the DVD format per household. This is consistent with an adoption pattern of DVD hardware in which high-value consumers adopt early so that as later adopters enter the DVD market (and DVD penetration increases), the average demand falls.

The δ parameters pick up variation in the average national quality of a title across all markets. As one moves to a more valuable use of a movie (from rental to buying used, for example), the quality increases. However, comparisons across the four format-pricing types need to account for differences in the average value of $X_m \hat{\beta}$ for each title. For this reason, I report the average predicted quality estimates in Panel B. These estimates add $X_m \hat{\beta}$ to the average national quality parameters for each title, and make comparisons across the four format-pricing types meaningful.

The average predicted quality of different uses of a title across the four format-pricing types in Panel B are given by

$\hat{\delta}_{o,m,j} = \hat{\delta}_{o,j} + X_m \hat{\beta}_j$. The average predicted quality of a rental is slightly lower for the DVD format compared to VHS while the average predicted used and new sale DVD qualities are higher. There is a larger difference between the average predicted DVD sales qualities for the two groups of titles (rental versus sell-through priced) than there is on the VHS format. This is primarily driven by lower average quality estimates for children's titles on the DVD format, which drives down the average sales qualities of DVD titles that were sell-through priced on VHS.³² The decay rate for the quality of a purchase is estimated as the ratio of the average quality of a purchase in the second period and the average quality of a purchase in the first period for rental priced VHS titles and is 0.89. The relative value of renting versus owning is higher on the VHS format: I estimate that a consumer receives over 70 percent of the value of owning a VHS tape from renting it one time. The comparable figure for the DVD format is around 50–60 percent.

Panel C of Table IV reports values for the parameters τ and μ , which are calculated directly from the data. The τ parameter is the ratio of rentals to inventory and differs considerably across the two pricing regimes. VHS inventory is used more intensively for titles that are rental priced, producing 23.7 rentals per tape compared to 16.9 rentals per tape for sell-through priced titles. DVDs show almost no difference in the rental technology across the two sets of titles, producing 15.6 and 15.3 rentals, respectively. The μ parameter is the difference between the observed retail price and the observed variable cost of the rental. Retail markups are higher for the sell-through priced VHS titles and for DVDs: around \$2 compared to \$-0.03 for rental priced titles on the VHS format, and between \$0.38 and \$0.90 for both sets of titles on the DVD format. Sales markups by retailers are around \$40 in the first period for rental priced VHS but are around \$4 after repricing. Mark-ups in the first period for sell-through priced VHS and titles on the DVD format range from \$8 to \$10. The retailer markup on sales of used tapes is assumed to be equal to the price.

The quality of a second-period purchase is not identified directly for sell-through priced titles, because there are no data on

32. Anecdotally, trade press articles cite the ease of use of the VHS format for children as one source of this difference because VHS tapes can be inserted into a machine and automatically played without the need to press any additional buttons.

any actual second-period purchases for those titles. I construct an estimate of second-period quality for these titles as follows. The average difference between the first-period new purchase quality and the used purchase quality is estimated for each genre from the twelve rental priced titles in the top panel.³³ I then calculate the percentage split represented by the second-period purchase quality for these titles and apply that percentage to the sell-through priced titles in the second panel. For example, if rental-priced dramas have average used, period 2, and period 1 qualities of 1, 1.5, and 2, respectively, and a sell-through priced drama has used and period 1 qualities of 2 and 4, then the period 2 quality assigned to that title is 3.

One downside to estimating second-period quality for sell-through priced titles in this way is that unobserved differences in the second-period quality may be the reason that the firm chose to do sell-through pricing. In fact, this is predicted by the theoretical model. Fortunately, it is straightforward to bound this parameter, because the second-period quality is presumably greater than the used quality (and also less than the period-one new quality).

V.C. Scatterplots of Quality Estimates

Table IV provides the mean quality estimates for each of the four movie-format groups, but does not show the variation across titles that the estimates are able to capture through the large number of free demand intercepts. Figures I and II provide some insight into the nature of this variation.

The theoretical model makes two predictions for the firm's pricing decision based on the value of the rental and second-period sales markets: movies with (1) higher value in the rental market and/or (2) slower decay in the sales market should be more likely to be rental priced, all else equal. To test these predictions using my estimates, I need to scale each movie's quality parameters by its value in the sales market to make movies comparable. Thus, I scale each movie's estimated value in the rental and second-period sales markets by its value in the first-period sale market.³⁴

33. For children's titles, I used PG-rated "family" movies, which are primarily directed at the children's market.

34. I also need to map the estimated values into the positive number line, as the normalization in the demand specification is very unrestrictive and only normalizes the value of the first movie in the first market. As a result of this unrestrictive normalization, some movies may have estimated quality parameters

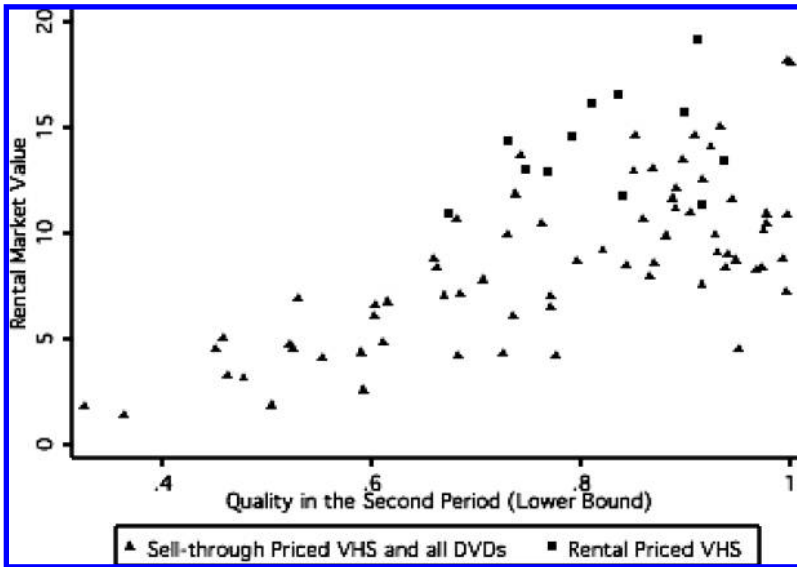


FIGURE I

Estimated Quality Parameters, All Titles (uses lower bound of second-period quality for sell-through priced titles)

Figure I provides a scatterplot of the estimated relative value of each movie in the rental market on the vertical axis. The estimated relative value of each movie in the second-period sales market is plotted on the horizontal axis.³⁵ I use the lower bound of second-period quality for the sell-through priced titles, calculated as $\delta_{u,j} + 0.0001$; using the average estimate of second-period quality instead of its lower bound gives very similar results. The predictions of the theoretical model are that rental priced movies should lie in the northeast part of the plane with sell-through priced movies lying closer to the origin. Figure I shows that the first prediction clearly holds: movies for which the firm chose price discrimination are more valuable in the rental market. The result for the second prediction is more ambiguous: the theoretical model predicts that the rental

that are negative, making ratios of the qualities difficult to interpret across movies. I use the exponential function for mapping quality parameters to the positive number line. This is done only for displaying relative quality estimates across movies in the scatterplots. Counterfactual estimates use the actual quality parameters.

35. The exact mappings are $\tau \cdot \exp(\delta_{u,j})/\exp(\delta_s)$ for the value in the rental market, and $\exp(\delta_{s,2})/\exp(\delta_s)$ for the second-period sales market.

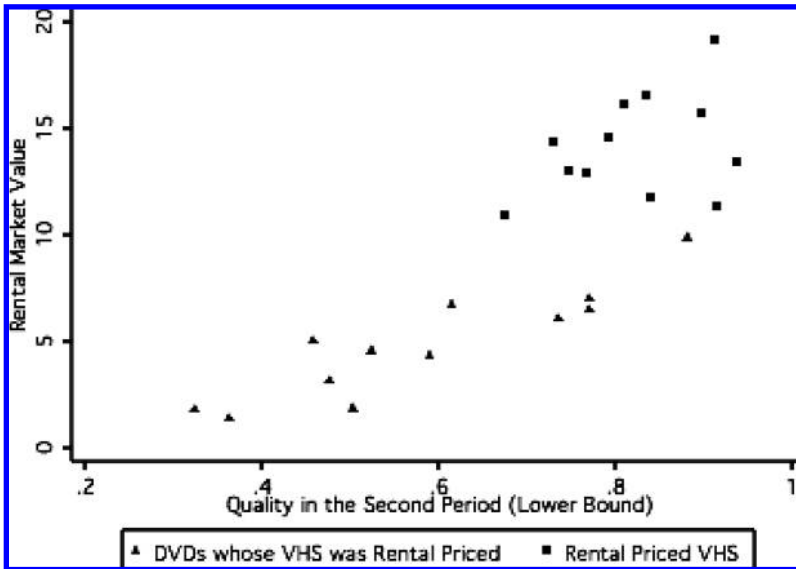


FIGURE II
 Estimated Quality Parameters, Titles whose VHS was Rental Priced (uses lower bound of second-period quality for DVD format)

priced titles would lie to the right of sell-through priced titles, and this pattern is weaker in Figure I. However, this prediction should be more difficult to show in the data because we do not directly observe second-period sales for sell-through priced titles.

A much clearer picture emerges if one compares the VHS and DVD formats for the set of movies that were rental priced on VHS. Figure II displays estimated quality levels for these twelve movies. Clearly, comparisons across the two formats (when they are priced differently) match the predictions of the theoretical model with the VHS format being both (1) relatively more valuable in the rental market and (2) relatively more valuable in the second-period sales market. This separation is not evident when comparing movies on VHS and DVD formats that were sell-through priced for both format types.³⁶

36. Figure II also uses the lower bound of the second-period sales quality estimates for sell-through priced titles, but the same qualitative patterns emerge if I use the average estimate of second-period sales quality.

VI. COUNTERFACTUAL EXPERIMENTS AND WELFARE ANALYSIS OF COPYRIGHT LAW

In addition to analyzing firms' pricing decisions, the estimated demand model allows me to examine the welfare implications of price discrimination under current U. S. copyright law. In order to do this, I use the estimated parameters in Table IV to predict market shares, variable profits for studios and retailers, and consumer surplus, assuming that studios choose the price or prices that maximize their profit for each title. I then recalculate market shares, variable profits, and consumer surplus under the assumption that studios adopt the "other" pricing regime in each of the four groups of title-format pairs, allowing for the studio's optimal price under the alternative regime. That is, I examine the outcomes if rental priced titles were instead sell-through priced, and vice versa. This counterfactual yields the welfare implications of alternative pricing strategies under U. S. copyright law.

As shown earlier, predictions about a firm's price discrimination strategy depend on the estimated benefits and costs of price discrimination. These benefits and costs depend on a movie's value in the rental market and its rate of decay in the sales market. However, retailer behavior can affect a movie's value in the rental market and may depend on the pricing strategy taken by the firm. One should take this into account when comparing the profitability of different pricing strategies. The next subsection discusses the relevant parameters for modeling the retail sector. Following that, I provide the results of the welfare analyses.

VI.A. Additional Modeling for Counterfactual Experiments

There are two choices for how to handle changes in retailer parameters, which are μ and τ . On one hand, one could write down a model of retailer competition in which μ and τ are determined endogenously. One challenge with this approach is that many of the observable competitive conditions at the retail level do not change across pricing types. Alternatively, one could adopt a less complete model of retailer competition but use the rich structure of the data to predict changes in μ and τ empirically under counterfactual pricing strategies. The benefit of this approach is that it retains the focus on the pricing decision of the movie studio and allows for considerable flexibility within the set of prices that are observed. It also allows for flexibility across

retailers that differ according to unobservable characteristics but have the same observable characteristics. The main drawback to this approach is that, while it may give quite accurate predictions about changes in μ and τ for pricing contracts that are observed, it is less informative about changes in μ and τ for prices for which we have no observations. In other words, out-of-sample predictions are more constrained. I adopt the second method.

For μ , I assume that each retailer receives the average markup observed for its “other” priced movies when examining the effects of the “other” pricing strategy. This is calculated directly from the data, and I report the average μ 's in Table IV. For retailer k , I use this average markup of rental priced movies for examining outcomes of a rental pricing strategy for titles that were actually priced for sell-through, and I use this average markup of sell-through priced movies for examining outcomes of a sell-through pricing strategy for titles that were actually rental priced. An analogous approach identifies markups of sales for each retailer. In addition to modeling retailer markups, I allow for a change in each retailer's intensity of inventory use under the counterfactual pricing regime due to the difference in the cost of a tape. In a method analogous to that used for retailer markups, I use the average of retailer k 's observed inventory usage of rental priced titles to give counterfactual inventory use for titles that were actually sell-through priced and vice versa for titles that were actually rental priced.³⁷

One limitation to this method is that a higher τ does not directly affect consumer utility. One worries about an effect like this if, for example, a higher τ leads to longer (and less desirable) wait times for consumers because of rationing. Assuming that retailers use rental priced tapes more intensively and that consumers do not like waiting, consumer welfare would thus be lower for rental-pricing regimes. Furthermore, the effect of rationing may change if the pricing of all titles changed.³⁸

37. I have also performed a number of robustness tests, such as calculating the average increase in inventory use for the two pricing regimes and applying that to each store's actual τ for each title. The average increase is around three (i.e., stores produce three times as many rentals from each tape for rental priced titles compared to sell-through priced titles). The results are not affected in any meaningful way. Alternatively, one could condition on additional variables when averaging to allow for a smoother mapping over prices. For example, one could regress μ and τ on pricing indicators and actual wholesale prices and use the estimated coefficients to predict the counterfactual μ 's and τ .

38. One could incorporate this type of effect with some additional assumptions on the utility functions. For example, one could allow the quality of a rental

Finally, the demand for used tapes highlights an important issue for producers of durable goods. I assume that the market for used tapes is constrained by the level of inventory purchased by retailers. Thus, I assume that retailers can only sell used tapes up to the level of their inventory, less one tape to keep for future rental business. In many cases, this leads to rationing of used tapes. This effect is quite interesting, as it highlights the importance of price discrimination in markets for durable goods where the firm does not control the second-hand market.

VI.B. Welfare Analyses

Analyzing the welfare effects of the current pricing strategies requires a comparison of the current outcomes to those under alternative pricing regimes. In each case, I assume that the copyright holder optimally chooses price. The welfare analyses proceed in two steps. In the first step, I calculate optimal prices, predicted market shares, profits, and consumer surplus under the current pricing strategy, and I compare this to actual prices, market shares, and profits. This gives an indication of how well the demand estimates capture variation in the data. Estimates that are far from actual may indicate a poor fit of the demand model. Once a reasonable fit has been confirmed, the predicted profits and consumer surplus estimates provide a baseline comparison for alternative pricing regimes. In the second step, I calculate optimal prices, market shares, profits, and consumer surplus under an alternative pricing strategy and compare these outcomes to the outcomes derived in the first step. For example, for analyzing the effect of rental pricing for the set of titles that are currently rental priced, I compare the outcomes under rental pricing to the current predicted outcomes. Recall that only demand-side moment restrictions are used for estimating the quality and taste parameters, and retailer-specific averages are used to estimate parameters for retail markups and inventory use. Thus, none of the estimated parameters relies on any assumptions of profit-maximizing behavior by the copyright holder and it is possible that either the current pricing policy or the alternative pricing policy can yield higher predicted profits.

The results of the counterfactual pricing decisions are contained in Tables V and VI. I start with Table V, in which the first

to decrease based on the estimated τ that is relevant to the pricing counterfactual.

TABLE V
COUNTERFACTUAL EXERCISES, VHS

	Actual	Current	Other	Mkt. seg.
Panel A: Rental priced titles (12):				
p_r^w	52.43	58.07	31.67	38.47
p_s (period 1)	109.13	105.13	41.41	38.57
p_s (period 2)	20.46	16.97	—	—
p_u	8.45	8.63	8.48	8.62
p_r	2.92	2.84	3.37	2.51
% new (period 1)	0.16	0.24	0.11	0.34
% new (period 2)	0.34	0.97	—	—
% used	0.40	0.32	0.52	0.34
% rent	29.35	31.84	25.19	37.98
Avg. studio profit (Mil.)	5.77	5.68	4.86	4.24
Avg. retailer profit (Mil.)	3.01	3.10	3.41	2.40
%Δ studio profit	—	-1.55	-14.45	-25.30
%Δ retailer profit	—	2.98	10.20	-22.44
%Δ consumer surplus	—	—	-21.42	-17.77
Panel B: Sell-through priced titles (29):				
p_r^w	14.49	16.13	32.41	45.44
p_s (period 1)	24.00	25.70	76.13	19.49
p_s (period 2)	—	—	20.70	—
p_u	7.71	7.72	7.80	7.78
p_r	2.94	3.04	1.70	2.45
% new (period 1)	0.86	1.44	0.07	2.60
% new (period 2)	—	—	1.08	—
% used	0.81	0.48	0.36	0.11
% rent	25.43	24.08	46.65	29.74
Avg. studio profit (Mil.)	3.53	4.70	3.32	4.86
Avg. retailer profit (Mil.)	6.41	6.31	1.99	2.47
%Δ studio profit	—	33.09	-29.26	3.56
%Δ retailer profit	—	-1.51	-68.40	-60.86
%Δ consumer surplus	—	—	-11.15	-24.59

Retail and studio profits are weighted to include all outlets.

"Current" uses actual μ and τ .

"Other" uses counterfactual μ and τ .

"Mkt. Seg." uses μ_r and τ from rental pricing; μ_s from sell-through.

two columns give actual and estimated market shares for the VHS format. The table is divided into two panels according to whether or not a title's VHS release was rental or sell-through priced. The first column lists actual prices, market shares, and variable profits for movie studios and retailers. The reported profits are the average variable profits for a title, assuming that markups and prices in the unobserved stores in each market are

TABLE VI
COUNTERFACTUAL EXERCISES, DVD

	Actual	Current	Other	Mkt. seg.
Panel A: VHS was rental priced (12):				
p_r^w	15.55	15.22	32.08	42.09
p_s (period 1)	23.75	24.05	75.64	22.49
p_s (period 2)	—	—	21.41	—
p_u	10.29	10.29	10.31	10.29
p_r	2.81	2.82	1.52	2.14
% new (period 1)	5.66	7.48	0.29	9.71
% new (period 2)	—	—	2.90	—
% used	0.28	0.05	0.67	0.02
% rent	24.47	26.49	54.16	33.00
Avg. studio profit (Mil.)	0.96	1.15	0.72	1.22
Avg. retailer (Mil.)	0.58	0.63	0.35	0.32
%Δ studio profit	—	20.29	-37.33	6.25
%Δ retailer profit	—	7.39	-44.84	-49.76
%Δ consumer surplus	—	—	-8.81	29.78
Panel B: VHS was sell-through priced (29):				
p_r^w	17.16	17.77	36.03	42.83
p_s (period 1)	27.77	28.86	79.80	24.03
p_s (period 2)	—	—	23.48	—
p_u	11.57	11.39	11.45	11.46
p_r	2.81	2.95	1.72	2.31
% new (period 1)	2.62	3.93	0.08	5.35
% new (period 2)	—	—	2.87	—
% used	0.34	0.24	0.36	0.08
% rent	22.80	25.71	45.16	30.40
Avg. studio profit (Mil.)	0.72	0.84	0.57	0.91
Avg. retailer profit (Mil.)	0.61	0.61	0.28	0.24
%Δ studio profit	—	16.91	-32.57	7.53
%Δ retailer profit	—	0.19	-54.91	-60.71
%Δ consumer surplus	—	—	-7.21	9.18

Retail and studio profits are weighted to include all outlets.

"Current" uses actual μ and τ .

"Other" uses counterfactual μ and τ .

"Mkt. Seg." uses μ_r and τ from rental pricing; μ_s from sell-through.

the same as the markups and prices I do observe. Actual market shares are around 25–29 percent for rentals of titles on VHS. Column (2) solves for the optimal monopoly price, given the parameter values. In Panel A, covering rental priced VHS titles, estimated prices, and market shares are quite close to the actual. In Panel B, covering sell-through priced VHS titles, the optimal price is estimated to be slightly higher than the actual price, with

slightly higher profits to the studio. Overall, the estimated prices indicate a reasonably good fit to the data. Subsequent comparisons will be to the results in column (2).

Column (3) gives predicted market shares and profits under the “other” pricing regime. For Panel A, which contains rental priced movies, this corresponds to the adoption of sell-through pricing. I again solve for the optimal wholesale price. Markups and inventory use are modeled as described in the previous section. At these parameter values, the use of sell-through pricing results in a roughly 15 percent reduction in profits on average for the studio. Retailers would be 10 percent better off under this pricing regime, and consumers would be worse off under this scenario, with consumer surplus falling roughly 21 percent. In Panel B, the third column corresponds to counterfactual outcomes under rental pricing. Both studios and retailers are worse off under rental pricing for this set of titles. This is consistent with reports in industry trade journals and interviews about the expected effects of rental pricing for such movies. Consumers are also worse off.

Note the effects of rental pricing strategies to limit the size of the used market. Studios receive no revenues from these sales and price new tapes to shrink the supply of used tapes under the rental pricing strategy. The shrinking of this market also occurs because video stores are assumed to use inventories more intensively under rental pricing, thus carrying smaller inventories that can subsequently be resold.

Unlike the U. S. system, copyright laws in many other countries (most notably, the European Union and Australia) permit copyright holders to control subsequent use of a copyrighted good. This has led firms to adopt direct price discrimination in these markets. Column (4) gives results under market segmentation, similar to the pricing policies observed in countries with E.U.-type copyright laws. Under this regime, firms charge different prices to retailers and consumers on the first day of a movie’s video release, but I assume they do not engage in intertemporal price discrimination.³⁹ I adopt parameter values of μ_r and τ that are appropriate to rental pricing in this exercise. I estimate that market segmentation makes firms worse off compared to rental pricing for movies in the upper panel. Consumer surplus decreases by 18 percent. The lower panel shows a positive

39. The assumption of no intertemporal price discrimination follows the actual current practice of firms in these markets.

effect for studios under E.U.-type pricing, although retailers receive lower profits than they would have under rental-pricing, and consumers are worse off.

Table VI provides the same results for the DVD format. The comparison between the first two columns indicates a good fit of the model. Results of the experiment of adopting rental pricing for DVDs are shown in column (3). Studios and retailers are estimated to be worse off under rental pricing for both groups of titles as are consumers. Column (4) considers direct price discrimination (market segmentation). Studios are estimated to increase their profits by about 6–8 percent under this pricing regime compared to the sell-through pricing strategy used currently in the United States. Consumers also benefit significantly under this policy. On the other hand, the use of market segmentation is estimated to make retailers worse off.⁴⁰

Comparisons of “current” versus “other” results for Tables V and VI provide average results across titles and indicate that firms’ pricing choices are consistent with what my model predicts to be the correct choice, on average. Examining firms’ decisions for individual titles (not reported separately) shows that my model predicts the same marketing scheme as that chosen for thirty-five of the forty-one movies on the VHS format and for thirty-two of the forty-one movies on the DVD format. The estimated difference in profits across the two pricing regimes ranges from close to zero (there are nine movies where the predicted difference is less than 3 percent) to one movie with a 99 percent predicted difference. For the vast majority of titles, the predicted difference in profits is between 20 and 40 percent. There are not obvious differences by genre or rating classification in what the model predicts to be optimal, compared to actual choices.

One could also examine the outcomes among current VHS participants under the assumption that everyone in the VHS market eventually adopts DVD technology by replacing the product quality parameters for each title-use pair under the VHS format with the quality parameters for the same title-use appropriate to the DVD format. Although not reported here, this exer-

40. Anecdotally, the average predicted prices under this scenario (\$43 for retailers and \$24 for consumers for the set of sell-through priced titles) are close to some actual prices charged for recent sell-through priced DVD releases in the United Kingdom. For example, *Garfield—The Movie*, with U. S. theatrical box-office receipts of \$75 million, was released in the United Kingdom recently at prices of £15.99 and £11.99, or \$30.74 and \$23.05, for retailers and individuals, respectively.

cise indicates that as the VHS market adopts DVD technology, rental pricing becomes a more profitable strategy compared to sell-through pricing. Despite the higher relative estimated quality of the DVD technology for owning, the population that was using VHS technology in 2000 and 2001 differs from their DVD counterparts in the overall utility that it receives from watching movies (the β 's). As a result, studio profits are estimated to be higher under a rental pricing strategy for the group of titles that were rental priced on VHS (but lower under a rental pricing strategy for titles that were sell-through priced on VHS).⁴¹

VII. CONCLUSION

Firms respond strategically to the legal restrictions imposed upon them and the technologies they face. As a result, giving additional control to a copyright holder may affect pricing strategies, which may impact consumer surplus as well as producer surplus for firms that use copyrighted goods as inputs (e.g., retailers). To identify factors influencing firms' optimal responses to U. S. copyright law, I empirically examine the outcomes of two pricing strategies used by firms for products that are identical in content but distributed via an old established technology and a new emerging technology. I show that the decision to price discriminate depends on the expected costs and benefits of doing so, and I provide empirical evidence that firms account for the costs and benefits of indirect price discrimination when choosing their optimal pricing strategies. Specifically, both demographic effects and product quality levels differ across the VHS and DVD formats and contribute to the different pricing strategies chosen for these two formats. However, the most important difference for explaining firms' pricing decisions seems to be the relative value of owning a movie, which varies by movie and also by format.

I examine the welfare effects of the current price discrimination strategies used by firms in the United States and find that indirect price discrimination benefits copyright holders but generally harms retailers. Consumer welfare is highest under the current price discrimination strategies in use; thus, for some titles, indirect price discrimination benefits consumers, while for other titles, consumers are made worse off by this form of price discrimination. I also estimate the welfare effects of an alterna-

41. For details, see the working paper version of this paper from June 2006.

tive form of copyright protection that would allow for direct price discrimination, and I find that price discrimination under this law tends to benefit copyright holders and consumers at the expense of retailers.

Future research could examine the effects of indirect price discrimination when used in conjunction with revenue-sharing contracts. Such contracts were widely used for rental priced movies on the VHS format in the late 1990s, and could affect social welfare in the future if indirect price discrimination were adopted for DVDs. By reducing some of the inefficiencies of indirect price discrimination, revenue sharing may help to mitigate welfare losses due to copyright restrictions and would make indirect price discrimination even more attractive.

DATA APPENDIX

The auxiliary data sources outlined in Section III are used to define market size based on geographic size, format use, and outlet market share (to weight the observations from video rental stores). Geographic market size is based on zip codes. Clearly, zip code areas are designed to provide convenient local areas for the purposes of delivering mail, rather than as definitions of local markets. However, zip code areas appear to be a reasonable demarcation between markets in this setting: the average zip code area contains approximately 24,000 people and 2.6 video retail stores. Larger areas, such as four-digit zip code areas or Metropolitan Statistical Areas (MSAs) are also feasible ways of attaching local demographic and business listing information but seem to cover too large a geographic area for most video store customers.

For format use, I use Centris data on DVD hardware penetration. Centris surveys consumers each month on whether or not they own a DVD console and weights each consumer survey response according to a demographic weighting scheme.⁴² The Centris data begin their coverage in the late 1990s and continue through June 2001. I aggregate the individual surveys in each state to calculate an implied state-level DVD hardware penetration rate. Due to the limitations of the survey size in each month and the noisiness of the weighting scheme, I then fit a linear trend in each state across the eighteen months of January 2000

42. Karaca-Mandic [2003] provides more detail on the Centris data.

through June 2001. I use these fitted penetration rates in each month in each state as the actual penetration rates, and I assume that they are uniform within a state during that month.⁴³

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

$$(8) \quad \begin{aligned} N_{m,t}^{VHS} &= [HH \cdot (0.90 - DVD_t)] / STORES_{m,y} \text{ and} \\ N_{m,t}^{DVD} &= [HH \cdot DVD_t] / STORES_{m,y}, \end{aligned}$$

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 zip code from the 2000 U. S. Census, and the variable DVD_q is the penetration rate of DVD hardware in the relevant state and month.⁴⁴ The variable $STORES_{m,y}$ is the number of video specialty stores listed in the phone book for that zip code in year y . I observe roughly one of three stores in each zip code neighborhood. Unfortunately, I do not observe rentals and sales at other stores. Dividing N by the number of stores in the market inflates my observed sales and rentals at a single store to be representative of the local zip code area under the assumption that the unobserved stores have the same characteristics and sales as the observed store and that phone book listings represent the total population of video specialty stores.

The market for purchasing VHS tapes and DVDs also includes used tapes from stores' rental inventories. Unfortunately, the primary data source does not record sales transactions separately as used or new. 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 title at a 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-

43. One would, of course, like to have even more detailed information on these penetration rates, but these are the best data available, to my knowledge.

44. I match up titles to the monthly state penetration figures based on the month in which a title was released. The figure for overall VCR penetration (0.90) is from the VSDA 2002 Annual Report.

TABLE VII
MARKET SHARES OF ALTERNATIVE DISTRIBUTION CHANNELS: RENTALS AND SALES

Retail outlet	VHS rental	VHS sales	DVD rental	DVD sales
Video specialty (percent)	76.8	22.9	73.8	10.0 ^a
Other brick and mortar/grocery stores, etc.	23.2	10.7	17.1	30.0 ^b
Internet (Netflix, etc.)	0	1.9	9.1	10.0
Discount merchandiser (i.e., Walmart, etc.)	0	55.1	0	40.0 ^c
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.

a. Includes Blockbuster at 7 percent (mostly previewed DVDs) and an allowance for other video specialty stores.

b. Includes Best Buy at 20 percent, Circuit City at 5 percent, and an allowance for others at 5 percent.

c. Includes Walmart at 29 percent, Target at 8 percent, and an allowance for others at 3 percent.

survey data in Table VII. 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).

To weight the observed rentals and sales according to the market share of the stores in my database, I use an auxiliary dataset on phone survey data that asks respondents for information on where they purchased and rented videos. Table VII outlines market shares of rentals and purchases according to the type of retail outlet where rentals and purchases occurred.⁴⁵ Rentrak's data cover the population in the first row of Table VII, "video specialty retailers," and I make use of the data in the other rows of Table VII to weight my estimated market shares. As shown in Table VII, video specialty retailers 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 nonspecialized retail outlets, and so it is important to weight the sample accordingly.

I assume that purchases from discount merchandisers and internet firms, etc., occur with equal probability across zip code areas and that used tapes are only sold by video specialty stores. The

45. The table is constructed from data gathered on consumers' purchase and rental habits by Alexander and Associates, and reflects market shares as of the spring of 2002.

phone survey data include both used and new sales. Thus, the weight in Table VII gives the weight to be applied for all sales (used plus new). To get the correct weight for new sales, I calculate the total number of weighted sales, subtract used sales, and calculate the appropriate weight for new sales. I do this for each store-title pair on each format, using format-specific weights from Table VII. Now I can write down the relevant market size for each store-format-product as

$$\begin{aligned}
 N_{r,m,t}^{VHS} &= 0.768 \cdot N_{m,t}^{VHS}, \\
 N_{u,m,t}^{VHS} &= N_{m,t}^{VHS}, \\
 N_{s,m,t}^{VHS} &= W_{VHS} \cdot N_{m,t}^{VHS}, \\
 N_{r,m,t}^{DVD} &= 0.738 \cdot N_{m,t}^{DVD}, \\
 N_{u,m,t}^{DVD} &= N_{m,t}^{DVD}, \text{ and} \\
 N_{s,m,t}^{DVD} &= W_{DVD} \cdot N_{m,t}^{DVD},
 \end{aligned}
 \tag{9}$$

where W_{VHS} and W_{DVD} are vectors of new sales weights for each store-title pair on VHS and DVD formats, respectively. This definition of market size effectively weights the sample of stores appropriately to reflect the national market.⁴⁶ 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 not possible.

Table VIII shows total activity levels in the data as well as weighted totals. Most of the sales that occur in this population of stores are sales of used tapes. The weights applied to new sales are much larger, as I discuss in the estimation section. The ratio of total weighted sales to total weighted rentals across the four quadrants shows a higher overall level of weighted sales for DVDs compared to VHSs: 29.9 and 34.5 percent of rentals for DVDs versus 13.2 and 7.5 percent of rentals for the same titles on VHS format. Note that by comparing the different titles on the DVD format, one should get a sense of the importance of the endogeneity of the sell-through pricing decision. DVDs are priced the same for all titles, so the extent to which sell-through priced titles sell better on DVD than rental priced titles should be due to unobservable characteristics of the titles that make them

46. I have also estimated the model assuming that sell-through priced VHS titles have the same representation across video stores and mass merchandisers as DVDs. This does not change the results in any meaningful way.

TABLE VIII
WEIGHTED QUANTITIES OF RENTALS AND SALES

	VHS			DVD		
	Rentals	Used sales	New sales	Rentals	Used sales	New sales
Panel A: Rental priced titles ($N = 12$):						
Total per title ('000)	1,112.2	20.3	0.2	129.6	3.7	1.5
Weighted total per title	4,054.9	56.8	248.5	491.7	10.4	136.6
Ratio, weighted sales/ rentals (percent)			7.5			29.9
Panel B: Sell-through priced titles ($N = 29$):						
Total per title ('000)	910.5	39.2	0.5	131.8	5.0	0.9
Weighted total per title	3,319.5	109.8	327.3	500.1	14.0	158.4
Ratio, weighted sales/ rentals (percent)			13.2			34.5

Tabulations compiled by author using data from Rentrak Corporation and Alexander and Associates for the forty-one titles used in the analysis, which were released between January 2000 and December 2001.

relatively more desirable to own. This difference in the ratio of sales to rentals for these sets of titles is 4.6 percent for DVDs (34.5 versus 29.9 percent). Overall levels of DVD activity (including rentals) are higher for sell-through priced titles, but overall levels of VHS activity are higher for rental priced titles.

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

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