

Online Content Pricing: Purchase and Rental Markets*

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Abstract

The digital era is changing purchase and rental movie markets. Low transaction costs make it easier for consumers to access online content and Digital Rights Management enables studios to provide durable and non-durable versions of their movies. I design a conjoint experiment to recover consumer preferences to determine the studio's best strategy in the online space. I find that heterogeneity in one-time versus repeat consumption preferences drives purchase and rental offerings. I also find that when consumers place a premium on accessing new content, they are less likely to inter-temporally substitute thereby increasing the firm's pricing power. Consistent with theory, commitment to future prices increases profits considerably. This supports retailers', such as Apple's, rigid pricing structure despite studios' push towards more pricing flexibility.

*This is work-in-progress. All comments are welcome.

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1 Introduction

The home video industry, which has seen a lot of changes since its inception in the 1970's, is now at the advent of another impending change, facilitated by the digital era. Low transaction costs, enabled by high speed broadband, are driving consumers to online viewing where they can obtain instant access to content anytime anywhere. From a studio's perspective, Digital Rights Management (DRM) technology enables them to provide each user her unique copy, which if purchased cannot be transferred and if rented can be made to expire within a day or two. DRM thus enables shutdown of resale markets and makes incorporating planned obsolescence¹ easier. This paper empirically studies content pricing in such a context while also assessing the interaction of purchase and rental markets for durable goods more broadly².

As of December 2010, digital downloads of a newly released movie were available for purchase only while the rental option became available 1 month later. The purchase option was priced at \$14.99 and the rental option at \$3.99. This 'window' was likely created to price discriminate users willing to pay a premium to watch a movie in its new-release period. It is unclear whether this is an optimal strategy. First, if consumers are willing to postpone their consumption to later periods anticipating cheaper rental availability this strategy might not work. Second, if those who purchase at \$14.99 would do so even if there were a rental option available, shutting the rental market in a movie's new-release period may hurt profitability.

Rental markets play an important role in durable goods by solving the time-inconsistency problem arising from purchase markets (Coase 1972; Bulow 1982; Stokey 1981). This is because a rented product effectively converts the durable good to a non-durable one. In contrast, rental markets can also be used to sort out low valuation consumers who want to use the good only once, serving as a means of achieving indirect price discrimination (Varian 2000). Thus, a firm in deciding the best strategy to serve the market needs to understand

¹Starting with Swan 1970, a large literature has focused on optimal durability. See Waldman 2003 for a review.

²Desai and Purohit 1998 predict different market configurations when borrowed (i.e. leased) units depreciate at different rates than owned units. This is not applicable in our case where there are no product asymmetries between the digital purchase and rental copies of movies.

which and how many of its potential consumers are likely to value repeated consumption and which are likely to value one-time consumption. This is especially relevant in the context of movies, where some consumers may watch a movie only once while others may enjoy watching it repeatedly. This paper allows for this heterogeneity in preferences in determining what the best approach a content-provider trying to maximize his profits should take.

From a studio's perspective, it thus becomes important to understand whether consumers value the movie for a one-time viewing, for repeated viewing and if they are likely to postpone their purchase or rent occasions to later periods. Inter-temporal substitution can have huge implications on firm profitability. While these implications have been studied in the context of purchase markets (Nair 2007), their effect on rental markets has not been³. This paper finds that to the extent the good is valued as a one-time consumption good, postponement can hinder a firm's profitability in the rental market.

Currently, studios do not know much about consumer tastes specific to their movies⁴. This is because studios, as well as firms in many markets, do not have access to consumer preference data before launching their product in the market. To help firms understand and measure consumer preferences this paper designs an experimental study⁵. The design of this experiment uses the conjoint setting⁶ while incorporating the inherent dynamics that govern a consumer's purchase, rent or postponement behavior⁷. The experiment aims at recovering consumers' 1) repeat-consumption utility 2) time-period specific first-time consumption utility (this allows consumers' valuation to be different the first time they consume it) and 3) price-sensitivity.

By asking consumers to make trade-offs between Buying, Renting and Postponing and

³Dasgupta, Siddarth and Silva-Risso 2007, Mortimer 2007 empirically study purchase and rental markets but treat the two as vertically differentiated products ignoring the link arising out of their relative durability.

⁴Unkind Unwind, *The Economist*, 19 March 2011.

⁵This means of collecting data falls under the broad category of preference measurement. See Netzer, Toubia et al 2008 for an overview on recent advances in preference measurement.

⁶See Green and Srinivasan 1979;1990 for an overview.

⁷Papers that have incorporated the underlying structure governing consumers' decision processes in a conjoint setting include Gilbride and Allenby 2004; Iyengar, Jedidi and Kohli 2008; Dubé, Hitsch and Jindal 2009.

varying the current and future prices and the time the future prices come into effect, I recover their underlying preferences. I restrict consumers' consideration set to the digital world by informing them that the movies they will see in the survey will be available through digital download/streaming only. These preferences are then used to solve a dynamic equilibrium between the consumers and the firm to determine the firm's best strategy.

Currently, Apple through its push for simplicity is able to maintain a relatively simple pricing policy - \$14.99/\$3.99 to purchase/rent a new movie and \$9.99/\$2.99 to purchase/rent a catalog title. However this is changing as studios demand pricing flexibility and increasingly explore and use other platforms to distribute their movies (Facebook, Youtube, studio websites)⁸. Apple's current policy, to some extent, gives studios (although they are likely unaware of it) a credible commitment mechanism. When studios have relative pricing flexibility, they will have incentives to cut prices much as we have seen with DVDs thus leading to a world in which commitment may no longer be possible⁹. This is likely to lead to lower profitability as rational consumers expecting future price cuts postpone their decisions to later time periods. I evaluate a studio's pricing policy under the no-commitment strategy and compare it to a world where commitment is possible.

The results, when a firm is not able to commit to a future price path, indicate that to the extent consumers place a premium on the new-release period the firm is better-off as consumers are less likely to engage in inter-temporal substitution. I also find that in cases when there is substantial heterogeneity in repeat-watch utility but almost none in the first-time watch utility, the purchase and rental markets can be used to sort between the high and low valuation consumers. However, when the high valuation consumers place a high premium on the first-time consumption, they substitute to cheaper rental consumption early on, waiting to purchase at later periods when prices are lower.

⁸Most retailers currently charge a fixed margin (around 30%). As studios explore different platforms it is likely that increasing retailer competition will drive this margin down. My model assumes away the studio-retailer relationship and takes into account only the studio in determining the best product and pricing strategy.

⁹Relatedly, Purohit 1995 shows that the presence of intermediaries causes quantities to be naturally restricted moderating the time inconsistency problem.

Comparing this to the case where the firm shuts down the rental market in the new-release period, I find that delaying the rental option decreases profits (by 7% in the case of Megamind). This is because while a few high valuation consumers shift to Purchasing, most consumers choose to postpone and the studio loses out on the low-valuation consumers who place a premium on the new-release period and are not willing to pay high prices in later periods.

Under the commitment strategy, I find that profits increase substantially (63% for Megamind). This is because commitment eliminates inter-temporal substitution, as consumers know that prices will not fall in the future, enabling the firm to charge high prices.

The results indicate that rental markets play an important role, especially in the digital era where consumers face lower transaction costs and firms have better control of revenues earned in the rental market. Purchase markets which were valuable to consumers wishing to avoid the hassle of going to rental stores to rent and return a movie lose this aspect of their appeal in a world where purchase and rental transactions are equally easy. Rental markets traditionally associated with low margins, as anyone who owned a copy of the DVD could effectively rent the movie out (e.g. Redbox), may seem appealing in a world where studios can limit what consumers do with their purchased content.

The next section describes the model, which forms the basis of my experimental design as well as my supply-side policy evaluations. Section 3 sets up the experiment to recover the relevant parameters of interest. Section 4 describes the demand estimation procedure followed by the Results. Section 6 evaluates the optimal pricing policy while Section 7 evaluates various counterfactual policies. Section 8 concludes.

2 Model

This section describes the model that governs consumers' consumption decisions as well as firms' pricing decisions. This model is used to design the experiment to identify the relevant

parameters in a realistic setting (demand-side) as well as determine the content-specific optimal pricing strategy (supply-side).

2.1 States

A consumer can be in one of three states 1) Not Consumed the content 2) Consumed + Does Not Own the content and 3) Consumed + Own the content. A consumer will be in state 1 if she has not yet purchased or rented, state 2 if she has rented, but not purchased and state 3 if she has purchased the content. I distinguish whether a consumer has consumed the content or not to allow for the fact that her valuations in the two states might be very different. This is especially true in the case of movies and books, where consumers anticipate that once having watched the movie or read the book they may no longer be interested in it. To account for preferences related to newness or recency of the content, the time since release t is also a state in the model.

Consumers are also affected by the aggregate of these states because they affect the prices charged by the firms. Consumers are assumed to have rational expectations about how the aggregate states evolve. This assumption will be evoked when I solve for the firm's no-commitment pricing policy.

Assuming that there are M discrete-types¹⁰ in the population, the state space can be expressed as (s^i, S, t)

where

$$s^i = \begin{cases} 1 & \text{if } NotConsumed \\ 2 & \text{if } Consumed, NotOwn \\ 3 & \text{if } Own \end{cases}$$

is individual i 's state at time t , $i \in \{1, \dots, M\}$

$S = S^1, \dots, S^m, \dots, S^M$ is the aggregate state vector consisting of the aggregate state-space for each type of consumer

¹⁰I assume a discrete-type rather than a continuous distribution of heterogeneity largely to limit the state space. With M types, the state space is $(|D| \times |D|)^M$ where D is the number of points the continuous states w, o have been discretized into.

$S^m = (w^m, o^m)$ where w^m is the share of type- m consumers who have already consumed the content at the beginning of period t and o^m is the percentage of w^m who own the content. Doing so allows me to keep both w^m and o^m between 0 and 1. The figure below depicts this aggregate state

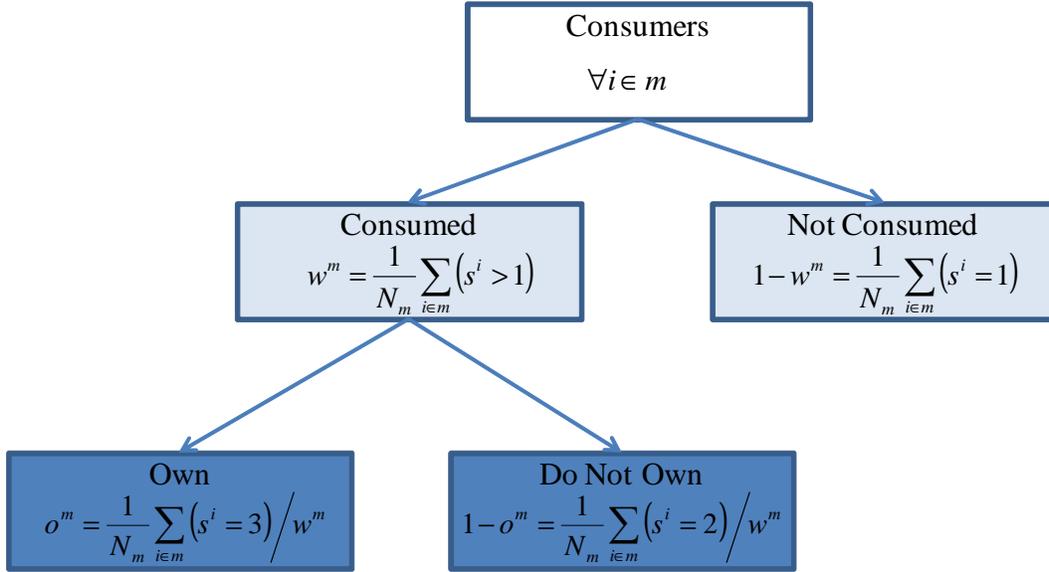


Figure 1: Aggregate state space

In the context of movies, consumers are currently used to seeing one price point for new titles and another for old titles (e.g. online movies for rent are priced at \$3.99 for new-release titles and \$2.99 for older catalog titles). This ‘commitment’ mechanism will be drawn on in the design of the survey where I present respondents with a ‘new-release price’ and a ‘future price’. In this case, only the time since release t is the relevant state variable. Consumers are assumed to take as given the prices that are effective at t given by the following equation

$$P = \begin{cases} P_{new} & \text{if } t < \bar{T} \\ P_{old} & \text{otherwise} \end{cases}$$

However, I build the model in the more general case where this kind of commitment may no longer be feasible. In such a no-commitment world, rational consumers will start taking into account how the aggregate state space will evolve and how these are likely to impact future

prices.

2.2 Per-period Utility

The type superscript M is suppressed in the following equations. Everything except price, which the firm sets uniformly across all types of consumers, is type-specific.

The type-specific per-period utility functions for those who do not own the content ($s < 3$) are given by

$$U_{buy}(s < 3, S, t) = \gamma + \kappa(t) \cdot 1(s = 1) - \alpha P_b(S, t) + \varepsilon_{buy,t} \quad (1)$$

$$U_{rent}(s < 3, S, t) = \gamma + \kappa(t) \cdot 1(s = 1) - \alpha P_r(S, t) + \varepsilon_{rent,t} \quad (2)$$

$$U_{opt}(s < 3, S, t) = 0 + \varepsilon_{opt,t} \quad (3)$$

In this specification, everyone who consumes the content gets a base utility γ . In addition I allow for the fact that some consumers may get an additional premium on consuming the content for the first-time. This difference between those who have not consumed the content before ($s = 1$) and those who have ($s = 2$) is captured through $\kappa(t)$.

In the context of movies, suspense thrillers may have a very high $\kappa(t)$ where consumers watching it for the first time do not know how the story will unfold, but once they have seen the ending no longer get the initial thrill upon watching the movie again later. Conversely, timeless movies which can be watched repeatedly and deliver the same amount of satisfaction everytime are likely to have $\kappa(t)$ close to 0 and a high repeat-utility γ .

The first-time watch bonus $\kappa(t)$ is also allowed to change with the time since release. This allows the excitement associated with consuming the content for the first time when it is new to be different from when it is older.

Those who own the content ($s = 3$) have an option of watching the movie again in the

future or not. Their per-period utility functions are given by

$$U_{consume}(s = 3, S, t) = \gamma + \varepsilon_{consume,t} \quad (4)$$

$$U_{notConsume}(s = 3, S, t) = 0 + \varepsilon_{notConsume,t} \quad (5)$$

State $s = 3$ is an absorbing state, as consumers who own the content continue to remain in this state. Typical models (e.g Song and Chintagunta 2003) account for this state by summing up the life-time value of owning through the term $\frac{\gamma}{1-\delta}$. Doing so in my model will lead to an asymmetry between purchase and rent arising out of their different option values. Consumers who choose to rent will have the option of choosing to watch again while consumers who own the movie will not have this option (i.e. they will be assumed to watch the movie every period). I relieve this asymmetry by allowing for the fact that even consumers who own the content have an option value associated with choosing to watch or not (Equations 4 and 5).

In equations 1-5 ε 's are the unobserved (to the researcher) shocks assumed to be independent across time and across all options¹¹ available to an individual in state s .

A consumer is assumed to know only her ε 's in the current time period. Her knowledge of the ε 's in the future time periods is assumed to be limited to their distribution¹². Thus a consumer cannot predict her choices in any future time period, she can only form expectations around them and these expectations inform her of the value of waiting in the current time period.

¹¹ $\varepsilon_{buy,t}$ and $\varepsilon_{rent,t}$ are likely correlated, as an individual who gets a shock that makes her more likely to consume the content in period t might be more likely to Buy as well as Rent the content. The current specification ignores this correlation for computational tractability. However, a nested logit specification with both Buy and Rent options nested within a Consume option that might capture the decision process more closely is under investigation.

¹²This assumption is typical in models analyzing dynamic demand.

2.3 Value Functions for the consumer

Separate value functions exist for each type of consumer and each state. Those who purchase the content get a per-period utility associated with buying the content today and an option value of consuming the content or not in the future. Thus the value function associated with owning the content can be written as

$$V_{buy}(s < 3, S, t) = U_{buy}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{l} V_{consume}(s' = 3, S', t + 1 | s, S), \\ V_{notConsume}(s' = 3, S', t + 1 | s, S) \end{array} \right) \quad (6)$$

where

$$V_{consume}(s = 3, S, t) = U_{consume}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{l} V_{consume}(s' = s, S', t + 1 | s, S), \\ V_{notConsume}(s' = s, S', t + 1 | s, S) \end{array} \right)$$

$$V_{notConsume}(s = 3, S, t) = U_{notConsume}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{l} V_{consume}(s' = s, S', t + 1 | s, S), \\ V_{notConsume}(s' = s, S', t + 1 | s, S) \end{array} \right)$$

Those who rent the content get a per-period utility associated with renting the content today and an option value of choosing to buy, rent or opt-out in the future.

$$V_{rent}(s < 3, S, t) = U_{rent}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{l} V_{buy}(s' = 2, S', t + 1 | s, S), \\ V_{rent}(s' = 2, S', t + 1 | s, S), \\ V_{opt}(s' = 2, S', t + 1 | s, S) \end{array} \right) \quad (7)$$

Those who choose to opt-out have an option value of choosing to buy, rent or opt-out in

the future.

$$V_{opt}(s < 3, S, t) = U_{opt}(s, S, t) + \delta Emax_{\varepsilon'} \begin{pmatrix} V_{buy}(s' = s, S', t + 1 | s, S), \\ V_{rent}(s' = s, S', t + 1 | s, S), \\ V_{opt}(s' = s, S', t + 1 | s, S) \end{pmatrix} \quad (8)$$

The difference between those who buy and those who rent the movie enters through γ , the repeat utility. Holding all else fixed, the probability to Buy is higher in consumers with a high γ . The difference between those who either choose to Buy or Rent and those who wait enters through $\kappa + \gamma$, the utility of a first watch. All else equal, those with a low $\kappa + \gamma$ are more likely to wait. This will form an important part of the identification strategy detailed in the next section.

2.4 Market share and endogenous state evolution

Assuming that the unobserved (to the researcher) shocks follow a Type-I extreme-value distribution the share of those consumers who have not consumed the content before and who choose to Buy and Rent can be written as

$$s_{buy}(s, S, t) = \frac{\exp(\bar{V}_{buy}(s, S, t))}{\exp(\bar{V}_{buy}(s, S, t)) + \exp(\bar{V}_{rent}(s, S, t)) + \exp(\bar{V}_{opt}(s, S, t))} \quad (9)$$

$$s_{rent}(s, S, t) = \frac{\exp(\bar{V}_{rent}(s, S, t))}{\exp(\bar{V}_{buy}(s, S, t)) + \exp(\bar{V}_{rent}(s, S, t)) + \exp(\bar{V}_{opt}(s, S, t))} \quad (10)$$

where $\bar{V}_j(s, S, t) = V_j(s, S, t) - \varepsilon_{j,t}$ $j \in \{buy, rent, opt\}$

The aggregate share of people who end up Buying and Renting the product each period can then be given as

$$Buy(S, t) = (1 - w) s_{buy}(s = 1, S, t) + w(1 - o) s_{buy}(s = 2, S, t) \quad (11)$$

$$Rent(S, t) = (1 - w) s_{rent}(s = 1, S, t) + w(1 - o) s_{rent}(s = 2, S, t) \quad (12)$$

The first term corresponds to those consumers who had not purchased or rented the content at the beginning of period t while the second term corresponds to those who had rented but not purchased.

The next period's state can be computed given the current state and the share of people who purchase and rent in the current period.

$$w' = w + (1 - w)(s_{buy}(s = 1, S, t) + s_{rent}(s = 1, S, t)) \quad (13)$$

$$o' = \frac{w.o + (1 - w)s_{buy}(s = 1, S, t) + w(1 - o)(s_{buy}(s = 2, S, t))}{w'} \quad (14)$$

Equation 13 sums the share of all consumers who had consumed the content at the beginning of period t , and adds the share of those consumers who consumed for the first time this period by either Buying or Renting. Equation 14 sums the share of all consumers who were owners at the beginning of period t , and adds the share of new owners who bought the content this period.

2.5 Profit functions for the firm

The monopolist firm gains from both the purchase and rental markets. The cannibalization between the purchase and rental markets, if any, is accounted for in the share equations. Note that despite the absence of resale markets, sold goods still compete with next-period sales. This is because the firm cannot sell additional units to consumers who already own the product and have incentives to cut prices to cater to the remaining consumers. Rational consumers, anticipating this, wait for lower future prices causing the monopolist to further lower his first-period prices. Similarly, to the extent consumers value the good for a one-time consumption, the monopolist will face the same problem in rental markets as well.

The current period profit for a firm that makes its content available for Purchase and Rent can be written as

$$\pi(S, t) = \sum_{m=1}^M q^m (Buy^m(S, t) P_b(S, t) + Rent^m(S, t) P_r(S, t)) \quad (15)$$

where q_m is the share of type- m consumers in the population.

The firm's optimal strategy is to choose that purchase and rental price at period t that maximizes the discounted value of its current and future stream of profits.

$$W(S, t) = \max_{P(S, t)} \pi(S, t) + \delta W(S', t + 1 | S) \quad (16)$$

2.6 Equilibrium

An equilibrium in this model is attained when 1) consumers maximize their utility having rational expectations about the firm's pricing policy and the evolution of the state space and 2) the firm behaves optimally having rational expectations about the evolution of the state space¹³.

For any given state (S, t) and price $P(S, t)$, consumers, based on equations 6-10, decide whether to Buy, Rent or Postpone having rational beliefs about the evolution of the state space as given by equations 13 and 14 as well as the prices firms will charge at those states. A firm in state (S, t) , based on equations 15 and 16, decides its optimal Purchase and Rental price taking into account the share of consumers who will consume at these current prices and those who will wait to consume at the future prices.

¹³I currently assume that there are no aggregate demand shocks. This implies that consumers and the firm know future prices and demand with certainty. I am exploring relaxing this assumption.

2.7 Discussion

Buyers or Collectors

It is possible that certain consumers have a high propensity to Buy irrespective of their future valuation, e.g. ‘collectors’ who want to have a large library of titles. However, this paper assumes that the future valuation forms an important part of the decision to Buy and ignores any ‘collector’ effect. It can be argued that collectors do so because they think they may watch the movie sometime in the future and value the option of watching highly. Moreover, while in the hardcopy world a consumer might get an additional utility from displaying a large collection this is less likely to be the case in a digital world where everything is stored in a cloud.

Theater-goers

A consumer’s decision to watch the movie in a theater is likely determined to some extent by the same structural parameters that govern her decision to buy or rent the movie. For example, some consumers who have a high premium associated with the new-release period are probably more likely to have some amount of substitutability between watching the movie in the theater and at home.

I accommodate consumers who have already seen the movie before in theaters by treating them as a separate type who are in the Seen ($s = 2$) state. The current model takes the consumer’s decision to watch a movie in the theater or not as exogenously given. Modeling her choice to go to the theater or not and how this effects home-video consumption is an interesting question in itself. From a firm’s perspective, this adds the strategic decision of when to release the movie for home-video. This is currently beyond the scope of this paper and is a suggestion for future work.

3 Experiment Design, Methodology and Data

This paper uses the conjoint setting to collect data relevant to the potential market for a specific movie. This section describes the experiment which is designed to identify the parameters in the preceding model. This section also describes the methodology used to gather the relevant data and summarizes the collected data.

3.1 Design and Identification

The experimental design builds off the important features of the Model section.

First, respondents are assumed to only know their demand shocks in the current period. Therefore I ask them to make trade-offs only in the current period. As respondents do not know what shocks they may receive in the future, they are not asked to specify their choices in future periods¹⁴.

Second, consumers who value repeated usage are more likely to buy the movie if the relative purchase and rental prices justify purchasing over repeatedly renting¹⁵. Consumers who want to see the movie only once are likely to rent it. Observing a consumer's trade-offs between Buy and Rent at fixed prices identifies her repeat-consumption utility γ . Thus, I am able to recover preferences relevant to a consumer's future valuations without asking her to make inter-temporal trade-offs¹⁶.

Third, consumers who place a premium on watching a movie when it is new are less likely to postpone their consumption to later time-periods. Observing a consumer's trade-offs between Rent and Postpone at fixed current and future prices identifies the value she places

¹⁴This contrasts with Dubé, Hitsch and Jindal 2009 who ask consumers to choose when they would purchase a durable good.

¹⁵Knox and Eliashberg 2009 incorporate this link between purchase and rental markets by considering the expected number of viewings in a consumer's Buy vs Rent decision.

¹⁶I assume that consumers have accurate beliefs about their preferences. This is likely to be true for movies after theatrical release due to the reviews and existing buzz. However, it is possible that consumers update their beliefs after seeing the movie. It is difficult to identify this 'learning' behavior in the current setting. Identifying learning may require multiple observations from the same consumer at different states. For example, Shin, Misra and Horsky (2010) use stated and revealed preference data to disentangle preference heterogeneity from learning.

on her first-time consumption now vs. later. This identifies $\kappa(t = 1)$ relative to $\kappa(t > 1)$. Note that the Postpone option is different from the None option typical to surveys. The Postpone option gives the consumer the option of buying or renting in the future.

Varying the time t at which the future price comes into effect and fixing $\kappa(T)$, I can recover $\kappa(t) \forall t = 1, \dots, T - 1$. In the experiment, t is allowed to take on 2 values - 1 month or 1 year. I chose t to take on the specific values of 1 month and 1 year as they can be singled out more clearly by respondents taking the survey, as opposed to varying t on a monthly basis. Allowing t to take on more than two values in the experiment can help recover a smoother decline function. $\kappa(T = 1year)$ is fixed such that $\kappa(T = 1year) = \kappa(t = 2)$. This identifies $\kappa(t = 1)$ and $\kappa(t = 2)$.

Lastly, variation in the absolute values of the purchase and rental prices recovers the price sensitivity parameter α . I also vary HD availability across choice tasks.

Thus, the choice task presented to a respondent consists of Buy, Rent and Postpone choices and is very similar to one an iTunes or Amazon consumer would face while deciding to purchase or rent a particular movie. An example of a choice task screen is shown in Figure 2. The attributes and their range of values are given in Table 1.

Identification of γ and $\kappa(t = 1)$ in a two-period model is illustrated in Appendix A.

Discussion on discount factors

The variation in the experiment can identify a discount factor as well. However, I fix the discount factor such that consumers have the same discount factor as the firm ($\delta_c = \delta_f$) for the following reason related to the supply-side analysis. If consumers have lower discount factors than the firm, in equilibrium the firm will end up exclusively renting to consumers. This is because consumers will have lower ownership utilities and will be willing to pay lower amounts to own the content. However, if they rent, the amount they are willing to pay will remain the same when they arrive at the next period (due to constant discounting). The firm, due to its higher patience, will effectively rent the product to consumers to exploit their

shortsightedness. This is explained through a simple model in Appendix B.

When this restriction is relaxed, estimated discount factors are in the range of 0.8 to 0.9. Renting in fact dominates in this case. By restricting $\delta_c = \delta_f$, the reduced preference for the future is picked up in how much the customer accelerates her current consumption ($\kappa(1)$ vs. $\kappa(2)$) and how much lesser she values repeat consumption (γ). In other words, the fact that she cares less about the future is reflected in her consumption values related to the future periods (both repeat and first-time consumption). Thus the only restriction is that they would trade-off dollar values of discount at current interest rates.

3.2 Methodology

The survey is designed to be movie-specific as different movies can have different parameters. For example, animated movies may have a high utility of repeat consumption while action-thriller movies may be associated with a high new-release period premium.

Respondents are first asked to select all the movies they might consider watching at home now or in the future from a set of pre-determined movies (Figure 3). The list of pre-determined movies consists of movies which have not yet been released for home video so that by design none of the respondents own or would have watched the movie at home. Ideally only 1 movie would be shown and all respondents asked to make trade-off decisions regarding the same movie. I include four movies in the list - Harry Potter, Megamind, Unstoppable, Tangled - to illustrate possible differences between movies. Respondents are then randomly assigned to one of the movies from their selections. Note that randomization gives us the entire distribution of consumers with an interest in the movie¹⁷.

As my main focus is to recover consumers' preference parameters by exploiting the setting of the digital world (no secondary markets and low transaction costs), I restrict the consumer's consideration set to the digital world by setting expectations accordingly. Re-

¹⁷If we asked respondents to choose only one movie among the list of pre-determined movies we would get only the right-side of the distribution consisting of people with an extremely high interest in the movie. Allowing for multiple selections and randomly assigning respondents to one movie from their selected set helps us achieve the complete distribution.

spondents in the survey are told that “The movie studios are considering moving entirely to digital offerings through the internet and stopping production of physical copies of movies.” and that “The movies you will see in this study will be available for online digital download only - they will not be available in the DVD or Blu-Ray format. In other words you can download the movie electronically but cannot own a physical copy or rent it from a kiosk or brick-and-mortar store. Due to exclusivity contracts these movies will also not be available through subscription services like Netflix.”

An instruction screen with an example choice task informs respondents of the choice tasks they will face. Respondents are then asked, regarding the specific movie they were randomly assigned to, to make trade-off decisions between 3 options: Buy Now, Rent Now and Postpone Decision each of which are described in detail below. The order of the choices is randomly rotated across tasks. Each respondent faces 12 such tasks.

Buy Now

This choice is associated with a purchase price and represents a decision to purchase in the current period. Respondents are made aware of the fact that if they Buy the movie Now they can enjoy it forever but cannot resell or rent it to others.

Rent Now

This choice is associated with a rental price and represents a decision to rent in the current period. Respondents are made aware that if they Rent the movie Now they have 48 hours to watch the movie and they have the option of re-renting it again in the future at the relevant prices.

Postpone Decision

This choice is associated with deferring an option until a later time period and includes the option to opt-out completely. The purchase and rental prices in the future are either lower

than or equal to the current prices. The time the lower prices come into effect can either be 1 month or 1 year.

3.3 Summary Statistics

The survey was released on December 11, 2010 to the online national pool available through Stanford GSB's lab. The survey was left open until February 3, 2011. During this time period none of the movies were released for home-video. The median respondent took 2.4 minutes to evaluate the set of 12 choice tasks.

Table 2 indicates the number of respondents per movie and highlights the percentage of people who chose an option at least once, always chose the same option or never chose a particular option. Sufficient variation in respondent's choice behavior is crucial in estimating the parameters of interest. About 8%-14% of the respondents always choose the Postpone option and 15% never choose the Postpone option (this includes 8% of the respondents who either choose to always Buy or always Rent) - these respondents are eliminated from the data while estimating the structural demand parameters. Having a wider range of prices in the choice tasks can mitigate this occurrence. To the extent that I eliminate those who never postpone, my estimated parameters will be biased downwards indicating a lower willingness-to-pay.

To make sure respondents understood what the Postpone option meant, they were asked to indicate, after completing the choice tasks, if they agreed with the following statements:

1. The Postpone option could be chosen when the new-release prices were too high for the Buy Now and Rent Now options presented but the future prices seemed reasonable
2. The Postpone option could be treated as a "None" option (i.e. when both the current and future options seemed unreasonable)

84% of respondents agreed with both statements indicating that the meaning of the Postpone decision option was clear to them.

Table 3 shows the results of a MNL model with the variates of the conjoint design serving as the independent variables. The results show that in general an increase in the current price increases the propensity to postpone while an increase in the future price decreases the propensity to postpone. Similarly an increase in the time the discount is applied decreases the propensity to postpone, i.e., the further away the discount, the higher is the likelihood of purchasing or renting now. This is preliminary evidence that respondents are taking into account the future options in their trade-off choices.

4 Demand estimation

I now recover the structural parameters governing a consumer’s decision to Buy, Rent or Postpone in a dynamic setting. The data collected is at the individual level with each individual having responded to 12 choice tasks. I estimate a type-specific heterogeneous distribution assuming that there are M discrete types in the population.

4.1 Likelihood function

The probability that an individual i of type m chooses option j in choice task c is given by equation 17

$$p_{i,c}(\beta_m) = \frac{\sum_j e^{\bar{V}_j(x_c, \beta_m)} I_{i,c}(j)}{\sum_j e^{\bar{V}_j(x_c, \beta_m)}} \quad (17)$$

where

$$j = \{Buy, Rent, Postpone\}$$

$I_{i,c}(j)$ are indicator functions reflecting individual i 's choice in choice task c

$\bar{V}_{buy}, \bar{V}_{rent}, \bar{V}_{opt}$ are the value functions (without the error term) associated with buying, renting and waiting at period 1 under the scenario presented in choice task c

β_m is the set of type-specific structural parameters $\{\gamma_m, \kappa_m(t), \alpha_m\}$ governing a consumer's decision

x_c are the variates of the conjoint choice task (the vector of purchase and rental

$$\text{prices } P = \begin{cases} P_{new} & \text{if } t < \bar{T} \\ P_{old} & \text{otherwise} \end{cases}, \text{ HD availability}$$

To arrive at Period 1 value functions, I first solve the nested fixed-point for the post discount periods $T > \bar{T}$. As prices do not fall after \bar{T} , the individual's value functions can be obtained through a contraction iteration. Knowing these value functions, I solve backward for the time-specific value functions. I assume a discount factor of 0.975 for estimation.

Aggregating the probabilities over choices, the type-specific individual-level probability is

$$p_i(\beta_m) = \prod_{c=1}^C p_{i,c}(\beta_m) \quad (18)$$

where C is the total number of choice tasks completed by an individual in the survey

As we do not know which type an individual belongs to, her individual-level probability is the weighted average of her type-specific individual-level probability across all types and can be written as

$$p_i(\theta) = \sum_{m=1}^M \pi_m p_i(\beta_m) \quad (19)$$

where π_m is the percentage of Type- m consumers in the population

and $\theta = \{\pi_1, \beta_1, \dots, \pi_M, \beta_M\}$

The overall log-likelihood across all individuals can then be written as

$$LL(\theta) = \sum_{i=1}^N \log p_i(\theta) \quad (20)$$

Maximizing this likelihood function is computationally difficult and I resort to the EM algorithm to recover θ .

4.2 EM algorithm

The EM algorithm (Dempster et al, 1977; Train 2008) is used to recover the underlying demand parameters. The EM algorithm solves for θ iteratively using the following recursion

$$\theta^{k+1} = \underset{\theta}{\operatorname{argmax}} \sum_{i=1}^N \sum_{m=1}^M q_{im}(\theta^k) \log \pi_m p_i(\beta_m) \quad (21)$$

where $q_{im}(\theta)$ is the conditional probability that individual i is of type m .

The steps for estimation using the EM algorithm are given in Appendix C.

5 Results

The results of the demand estimation for each of the four movies are presented in Table 4. I describe the estimation results through Figures 4, 5 and 6.

Watching the movie for the first time Figure 4 plots the willingness-to-pay for the first-time watch bonus in the movie’s period of release $\frac{\kappa(t=1)}{\alpha}$. From this Figure, one can see that for Megamind, one set of consumers places a high value on watching it for the first-time in its new-release period compared to the other type. Unstoppable and Tangled on the other hand are valued almost equally by both types.

Watching the movie for the first-time in its new-release period vs. later Figure 5 plots the additional value consumers place on the new-release period $\frac{\kappa(t=1) - \kappa(t>1)}{\kappa(t>1)}$. As anticipated, Unstoppable, an action thriller has a relatively high premium associated with watching it as soon as it is released. The low-valuation consumers for Megamind who although have a lower first-time watch bonus, value the movie much more in the new-release month than in later months.

Repeat-watch Figure 6 plots the difference in purchase and rent value functions driven by the repeat-watch utility of a movie. Here, we see that the repeat-watch utility (and not

the first-time watch utility) is what drives the difference between the two types of consumers for Unstoppable and Tangled.

Estimation of demand parameters for Harry Potter differs slightly as a large proportion (34%) of the respondents had already seen the movie before in theaters. As discussed in Section 2.7, these consumers are treated as a separate type whose actions are determined assuming they are in the *Seen* ($s = 2$) state. Type 1 consumers in the estimation results fall under this category. The estimation procedure for the rest of the sample remains unchanged.

5.1 Validation

Using the demand estimates obtained and the current prices charged for online purchase and rentals (\$14.99 for the first year and \$9.99 thereafter for purchases; \$3.99 for the first year and \$2.99 thereafter for rentals) I simulate what the current demand for purchase and rentals would be. These figures are then compared to the share of average units digitally downloaded vs. rented in 2010 (obtained from the revenue figures for 2010).

As can be seen from Figure 7 while the percentage of people choosing to purchase and rent in the survey compares closely to the reference point for the case of Harry Potter, the purchase shares are lower for the other three movies. This might be a trend we may see in the future, especially as forecasts into 2012 indicate a larger rent share relative to the purchase share (also seen in the Figure). It is also possible that the sample is more price-sensitive and hence more likely to rent at current prices charged. Alternatively, current sales could be affected by marketing mix variables which are not captured in the conjoint setting. Green and Srinivasan (1990) highlight the difficulty of conducting relevant tests of predictive validity due to the confounding effects of marketing mix variables.

6 Optimal Pricing Strategy without Commitment

I first evaluate the pricing strategy of the firm without the ability to commit. In the next section I compare this to a world where commitment is possible.

Having recovered the underlying parameters that govern consumers' preferences, I solve a dynamic equilibrium between the consumers and the firm. The algorithm for computing the optimal prices is presented in Appendix D. This algorithm adapts the one developed by Nair (2007) to incorporate rental markets as well. The algorithm is solved numerically using the TOMLAB interface between Matlab and the SNOPT solver, a system for constrained optimization.

Figure 8 plots the purchase and rental share evolution over time along with the equilibrium prices for Megamind. As can be seen, the high premium placed by consumers to watch the movie in its new-release period creates an increase in rental share in this period. For comparison, figure 9 depicts the rental shares if consumers did not place any additional premium on watching the movie as soon as it is released. Clearly, we observe a lot of inter-temporal substitution occurring in this case. As consumers no longer care about the 'newness' of the movie, they are more likely to wait for cheaper prices. Thus the firm engages in a price-discrimination strategy catering to the high-types early on and the low-types in later periods. When there is a strong incentive to watch the movie in its new-release period consumers are less likely to postpone their first-time consumption to later periods. This allows the firm to extract higher profits.

Lastly, the rental market plays a big role in generating revenues from both the high- and low- valuation consumers. Figure 10 plots the first-month and first-year revenues (per consumer) for this movie. In equilibrium, although high-valuation consumers substitute away from the purchase market to the cheaper rental option early on, the firm is better-off keeping the rental market open to cater to the low-valuation consumers. This cannibalization effect occurs because the high-valuation consumers place a high premium on the first-time watch. The firm could shut down the rental market in the new-release month to prevent this

cannibalization. However, doing so reduces the firm’s ability to cater to the low-valuation consumers who contribute a large part to its first-month revenues.

In contrast with Megamind, the high- and low- types of consumers of Unstoppable have almost the same first-time watch utility (Figure 4), but differ most in their repeat-watch utility. In equilibrium, for Unstoppable, the purchase market caters more to the high-valuation consumers and the rental market caters more to the low-valuation consumers. Revenues are shown in Figure 11.

7 Counterfactual Policy Evaluations

In this section, I evaluate the optimal strategy and profitability of a monopolist under three different scenarios. First, I compare the no-commitment policy world to the case where the studio can credibly commit to holding prices fixed over time. Second, I evaluate the loss in profitability if the studio were to delay rental availability by 1 month. Lastly, the equilibrium in a world with transaction costs to rent is evaluated.

7.1 Commitment

The studio’s pricing problem in this case is to choose that time-invariant purchase and rental price that maximizes his net profit.

$$[P_b, P_r] = \underset{P_b, P_r}{argmax} \sum_{t=1}^T \delta^t \sum_{m=1}^M q^m (Buy^m(S, t) P_b + Rent^m(S, t) P_r) \quad (22)$$

In this scenario, the studio is able to charge higher purchase and rent prices, as consumers know that prices will not fall in the future and no longer engage in inter-temporal substitution. Profits, in the case of Megamind, are 63% higher than in the no-commitment policy. Figure 12 plots the prices under the commitment scenario and compares it to the no-commitment policy, for the movie Megamind.

7.2 Delaying Rental Availability

From 2008 to 2010, digitally downloadable/streamable movies were not available for renting in the first month of a movie's home video release. In this counterfactual, I shut the rental market down in the new-release period and compare it to the optimal strategy evaluated in Section 6. The firm's profit in the new-release period in this case consists of revenues from the purchase market alone.

$$\pi(S, t = 1) = \sum_{m=1}^M q^m (Buy^m(S, t = 1) P_b(S, t = 1)) \quad (23)$$

Figure 13 shows the impact of delaying rent on profits in the new-release period. As can be seen, a few high-valuation consumers shift to purchasing, but the firm loses out on catering to the low-valuation consumers who will no longer be willing to pay high prices in later periods. Overall firm profitability decreases by 7%.

7.3 Transaction costs

Here, I evaluate the effect of transaction costs to simulate what an optimal strategy of the studio in the hardcopy world might look like. It is assumed that high-valuation consumers have higher transaction costs to rent than low-valuation consumers. The per-period utility from renting for the high-valuation consumers is given by

$$U_{rent}(s < 3, S, t) = \gamma + \kappa(t) \cdot 1(s = 1) - \alpha P_r(S, t) - tc + \varepsilon_{rent,t} \quad (24)$$

where tc is the transaction cost incurred if the consumer rents the movie from a brick-and-mortar rental store.

Figure 14 plots the equilibrium purchase and rental share evolution over time for Megamind. As can be seen, in the hardcopy world, the high valuation consumers are clearly catered to by the purchase market and the low types through the rental market. In the digital world, where purchase and rental transactions are equally easy, it is likely that consumers

who purchased hardcopies primarily to avoid the hassle of going to rental stores may now shift to renting movies online.

8 Conclusion

This paper shows that the digital era can change the way content is bought and sold. Renting can play a big role in generating revenues, especially when consumers place a premium on watching a movie in its new-release month. Lower transaction costs in the digital world increase the appeal of rental markets because renting repeatedly no longer involves incurring recurrent transaction costs. Shutting down rental markets in a movie's new-release month can negatively impact profitability as consumers are less likely to shift to purchasing but more likely to postpone their consumption to later periods.

I find that commitment has a considerable impact on profits. To some extent, Apple's current push for simplicity and maintenance of a simple pricing policy gives firms this commitment mechanism. However, as studios explore other avenues of distributing their content they may face incentives to cut prices after the high valuation consumers have purchased or rented the movie, thus losing the ability to commit. To the extent the good is valued as a one-time consumption good, such incentives will lead to lower prices in rental markets as well. However, when consumers place a premium on watching a movie in its new-release month, they are less likely to postpone their consumption allowing the firm to extract higher profits.

The degree of durability is an important driver of purchase and rental offerings. When there is substantial heterogeneity in one-time versus repeat-consumption utilities, purchase and rental markets can be used to serve different types of consumers. In the extreme case, when a movie is highly valued for repeat watches, i.e. it is completely durable, it may become optimal to serve it only in the rental market. We see some evidence of this strategy where children's favorites like *Dumbo* are made available only for online rent.

These preference parameters were recovered using a conjoint experiment. The design of this experiment was based on the underlying decision process governing a consumer's decision to buy, rent or postpone her consumption. Asking consumers to make trade-offs only related to the current period, I am able to recover their current and future preferences. This setting can be used by studios and content-owners to measure consumer preferences before releasing their content.

Lastly, I have not considered subscription pricing in my analysis. I leave this for future work, where knowledge of the distribution of preferences across all types of movies will be required to determine appropriate subscription bundles and prices.

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9 Figures



Harry Potter and the Deathly Hallows - Part 1 is and will be available for purchase or rent via online digital download only. **If these were your only options, which would you choose?**

Option	Rent Now	Buy Now	Postpone Decision
New-release Price	\$7.99	\$12.99	
HD	Yes	Yes	
Future Buy Price			Option to Buy at \$9.99 after 30 days
Future Rent Price			Option to Rent at \$5.99 after 30 days

Choose by clicking one of the buttons above. Please take your time in carefully evaluating the options presented in this screen.



Figure 2: An example of a choice task faced by a respondent

Please select the movies that you might consider watching AT HOME now or in the future.
 (Multiple selections possible)



Figure 3: Selection Task

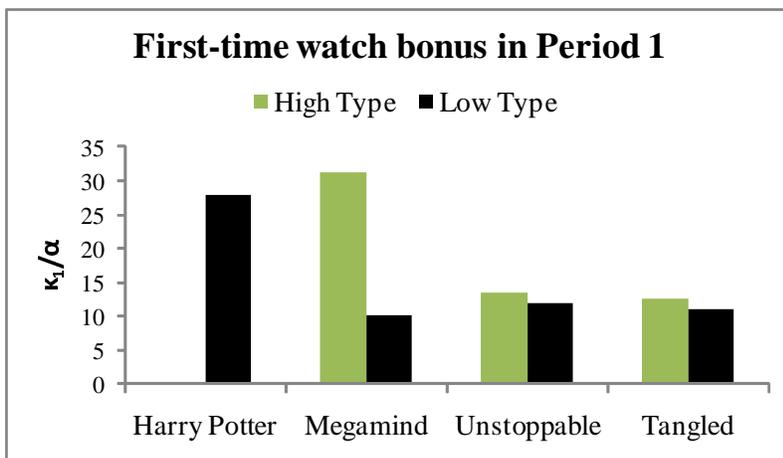


Figure 4: Demand Estimates: First-time watch bonus in the new-release period

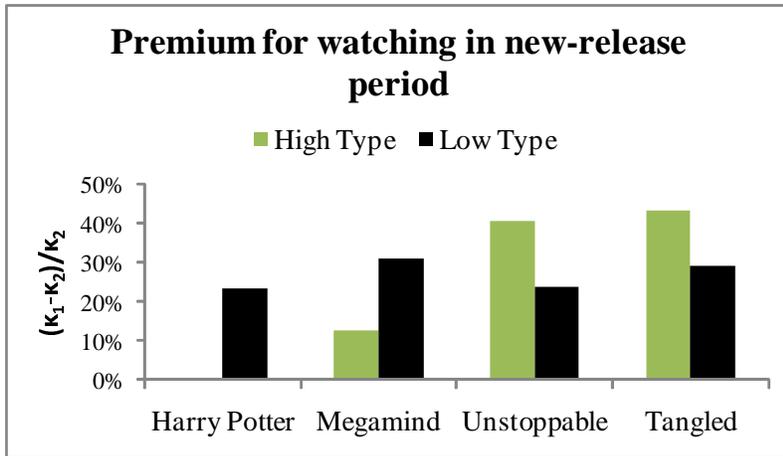
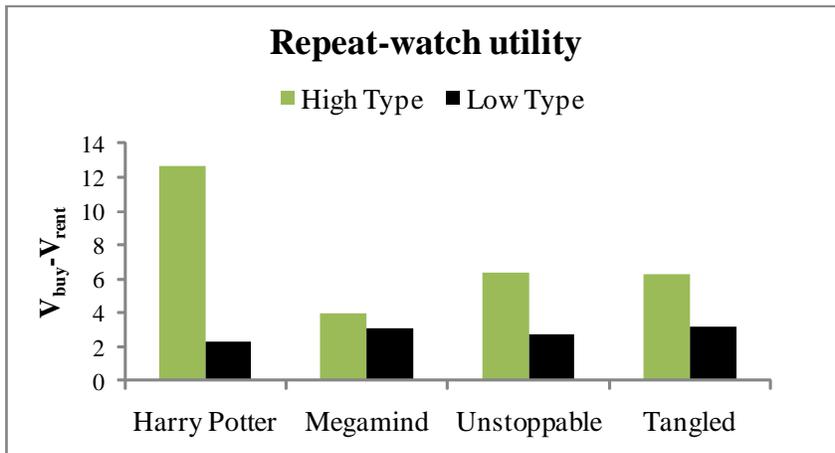
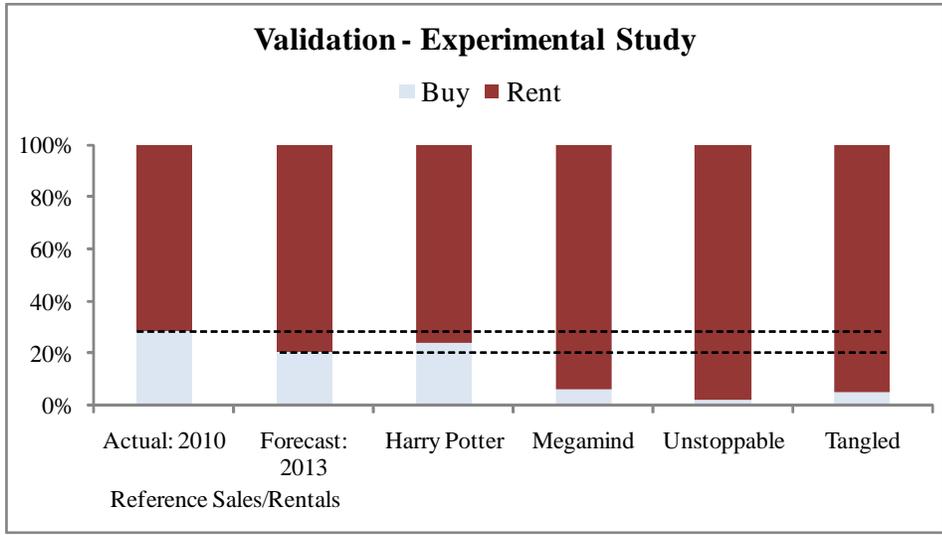


Figure 5: Demand Estimates: Percentage increase in first-time watch bonus arising from ‘newness’ of the movie



V_{buy} and V_{rent} are computed using the demand estimates at $P_b = P_r = \$10.99$ to illustrate the effect of the repeat-watch parameter

Figure 6: Demand Estimates: Repeat-watch utility



Reference Source: IHS Screen Digest, as made available by www.emarketer.com

Figure 7: Validation Results

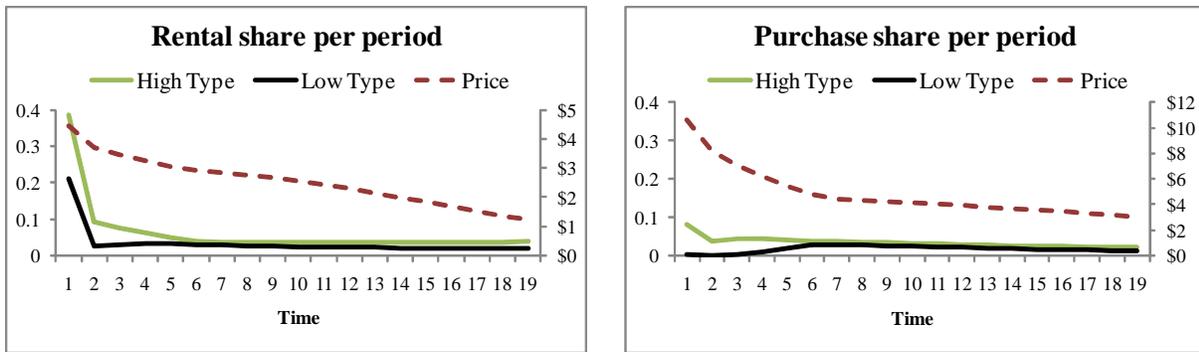


Figure 8: Equilibrium Purchase and Rental share over time - Megamind

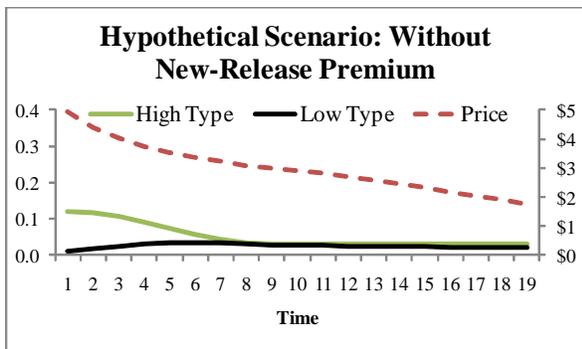
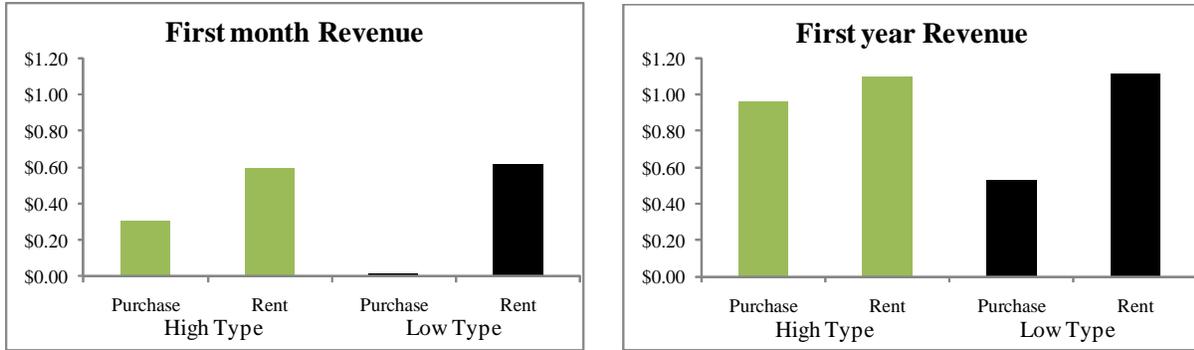


Figure 9: Counterfactual evaluation: Megamind rent share if consumers value new-release period the same as other periods



Revenues are per consumer. Revenues generated from each type of consumer are scaled down by the share of that type in the market.

Figure 10: First-month and First-year Revenues - Megamind



Revenues are per consumer. Revenues generated from each type of consumer are scaled down by the share of that type in the market.

Figure 11: First-month and First-year Revenues - Unstoppable

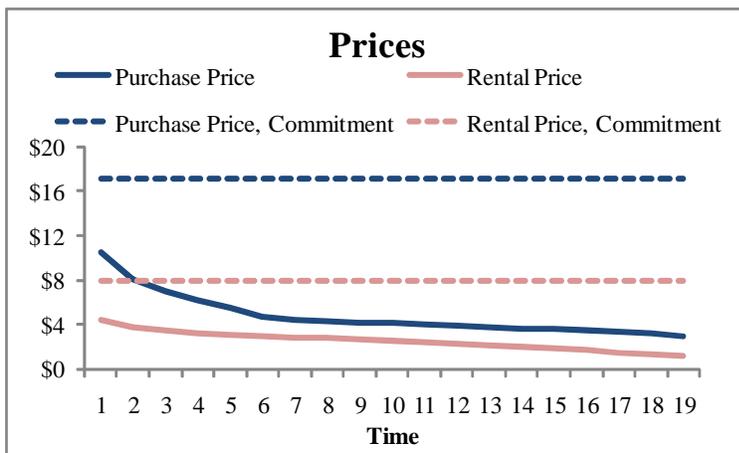
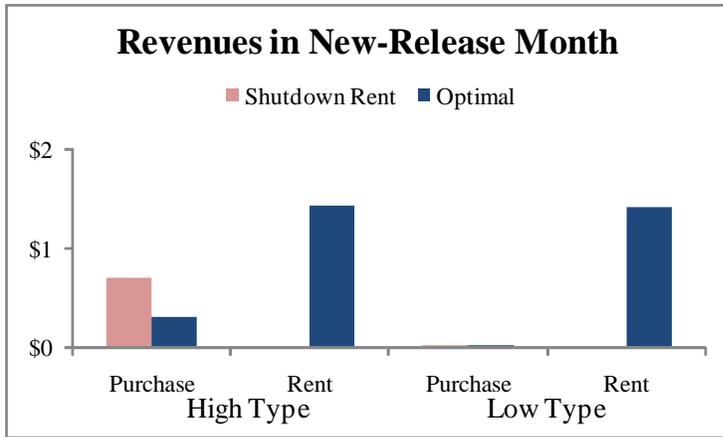


Figure 12: Equilibrium Prices for Megamind over time under the commitment and no-commitment policies



Revenues are per consumer.

Figure 13: Counterfactual Policy - Delaying Rental Availability (Megamind)

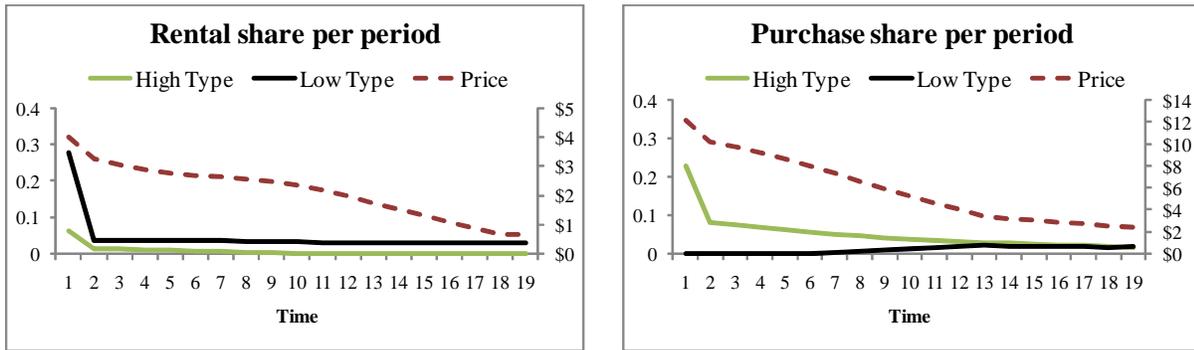


Figure 14: Counterfactual Policy - Transaction costs to rent (Megamind)

10 Tables

Conjoint variable	Possible values
Purchase Price	\$9.99, \$12.99, \$14.99
Rental Price	\$3.99, \$5.99, \$7.99
HD	Yes, No
Future Discount ^a	0%, 10%, 25% ^b
Time Future Discount is applied	1 month, 1 year

^aas applied to the purchase and rental price

^bthe price is displayed in \$ amount, rounded to the nearest \$.49 or \$.99

Table 1: Survey Design

	Harry Potter	Megamind	Unstoppable	Tangled
At least once				
Buy	63%	54%	43%	62%
Rent	62%	75%	81%	73%
Postpone	85%	86%	86%	86%
Never				
Buy	37%	46%	57%	38%
Rent	38%	25%	19%	27%
Postpone	15%	14%	14%	14%
Always				
Buy	7%	5%	1%	5%
Rent	2%	3%	7%	3%
Postpone	9%	8%	14%	8%
N	220	160	196	222

Table 2: Summary Statistics - Variation in the data

	Harry Potter		Megamind		Unstoppable		Tangled	
	U _{buy}	U _{rent}	U _{buy}	U _{rent}	U _{buy}	U _{rent}	U _{buy}	U _{rent}
P _{buy}	-0.43 ^a	0.14	-0.53 ^a	0.06	-0.54 ^a	-0.11	-0.79 ^a	-0.11
P _{rent}	-0.41	-1.51 ^a	-0.27	-1.46 ^a	-0.41	-0.95 ^a	0.07	-1.09 ^a
HD	-0.65 ^a	-0.27 ^a	-0.30 ^a	-0.16	-0.29 ^b	-0.31 ^a	-0.39 ^a	-0.25 ^a
P' _{buy}	0.29 ^b	-0.12	0.37 ^b	-0.03	0.24	0.21	0.59 ^a	0.21
P' _{rent}	0.43	1.26 ^a	0.30	1.11 ^a	0.50	0.55 ^b	-0.07	0.68 ^a
T	0.09 ^a	0.08 ^a	0.06 ^a	0.06 ^a	0.10 ^a	0.08 ^a	0.07 ^a	0.07 ^a
cons	2.40 ^a	1.69 ^a	1.58 ^a	1.90 ^a	2.57 ^a	1.66 ^a	2.90 ^a	1.44 ^a
LL	-1942.34		-1342.06		-1456.41		-1903.88	
N	168		126		141		172	

^a: Significant at the 95% level

^b: Significant at the 90% level

Table 3: Reduced Form MNL model (Postpone is the base option)

Parameter	Harry Potter		Megamind		Unstoppable		Tangled	
	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
Type-1								
Repeat-watch, γ	0.44	9.35	-1.78	-15.83	-1.58	-20.49	-1.53	-36.05
First-time watch bonus T=1, $\kappa(1)$	-		14.35	1.31	10.59	4.80	9.41	7.72
First-time watch bonus T>1, $\kappa(2)$	-		12.76	1.06	7.53	2.85	6.57	4.48
HD	-0.11	-0.86	-0.34	-0.67	0.23	0.48	-0.42	-1.44
Price-sensitivity, α	0.19	12.70	0.46	13.39	0.78	15.80	0.74	21.58
Type-2								
Repeat-watch, γ	-2.61	-30.95	-2.42	-18.91	-2.56	-25.35	-2.40	-21.73
First-time watch bonus T=1, $\kappa(1)$	11.08	3.89	11.98	11.60	13.82	12.93	12.37	12.02
First-time watch bonus T>1, $\kappa(2)$	8.99	2.70	9.14	7.60	11.19	9.11	9.58	8.11
HD	-0.17	-0.49	0.57	0.97	0.85	1.39	0.87	1.16
Price-sensitivity, α	0.40	13.56	1.17	10.83	1.15	15.87	1.12	12.40
Log likelihood	-1999.10		-1171.75		-1263.35		-1632.78	
% Type-1	0.34		0.35		0.26		0.50	
% Type-2	0.66		0.65		0.74		0.50	
N	168		126		141		172	

Table 4: Demand Estimates for all 4 movies

Appendix A: Identification in a Two-Period Model

Here I illustrate identification of the repeat-watch parameter γ and the first-time watch bonus in period 1 $\kappa(1)$ in a two-period model.

A consumer's choice-specific value-functions in a two-period model can be given as

$$V_{buy} = \kappa(1) + \gamma - P_{b,1} + \Gamma + \ln(e^\gamma + 1) \quad (25)$$

$$V_{rent} = \kappa(1) + \gamma - P_{r,1} + \Gamma + \ln(2e^{\gamma - P_{r,2}} + 1) \quad (26)$$

$$U_{postpone} = 0 + \Gamma + \ln(2e^{\kappa(2) + \gamma - P_{r,2}} + 1) \quad (27)$$

where

$P_{b,1}$ is the purchase price in Period 1

$P_{r,1}, P_{r,2}$ are the rental prices in Periods 1 and 2. $P_{b,2} = P_{r,2}$ as Period 2 is the last period

Buy vs. Rent Tradeoffs identify γ

Comparing Equations 25 and 26, after a few mathematical operations boils down to comparing e^γ with a constant $\frac{e^{P_{b,1}-P_{r,1}}-1}{1-2e^{P_{b,1}-P_{r,1}-P_{r,2}}}$. Higher the consumer's γ the higher is her value associated with Buying, at fixed Purchase and Rental prices. Thus, observing the shares of Buy relative to Rent identifies γ .

Rent Now vs. Postpone Tradeoffs identify $\kappa(t=1)$ (holding $\kappa(t=2)$ fixed)

Next, comparing 26 and 27, leads us to comparing $e^{\kappa(1)}$ to $\frac{2e^{\kappa(2)+\gamma-P_{r,2}}+1}{2e^{2\gamma-2P_r}+e^{\gamma-P_r}}$ which is a function of $\kappa(2)$ and γ and the prices. Knowing γ and fixing $\kappa(2)$ identifies $\kappa(1)$. Intuitively, if a consumer has a high premium associated with consuming the content sooner and a low repeat consumption utility, she is better-off renting now. In a two-period model, $\kappa(2)$ is not identified.

Appendix B: Equilibrium when $\delta_f > \delta_c$

Consider the case where the firm is choosing between one of two strategies: selling the product at P_b or renting the product repeatedly at P_r every period. In this case, assuming that the consumer has a repeat watch parameter γ , her value functions associated with buying and renting can be given by

$$V_{buy} = \frac{\gamma}{1 - \delta_c} - P_b$$

$$V_{rent} = \frac{\gamma - P_r}{1 - \delta_c}$$

If the firm decides to sell, the purchase price it can charge is $P_b = \frac{\gamma}{1-\delta_c}$. If the firm decides to rent, the per-period rental price it charges would be $P_r = \gamma$. The firm's net present value from repeatedly renting is $\frac{P_r}{1-\delta_f} = \frac{\gamma}{1-\delta_f}$. Since the firm is more patient $\delta_f > \delta_c$, the revenue it earns in the rental market is greater than the revenue it earns in the purchase market, i.e. $\frac{\gamma}{1-\delta_f} > \frac{\gamma}{1-\delta_c}$. Thus, in equilibrium the firm would always choose to rent repeatedly.

Appendix C: EM algorithm

The EM algorithm solves for θ iteratively using the following recursion

$$\theta^{k+1} = \underset{\theta}{\operatorname{argmax}} \sum_{i=1}^N \sum_{m=1}^M q_{im}(\theta^k) \log \pi_m p_i(\beta_m) \quad (28)$$

$$= \underset{\theta}{\operatorname{argmax}} \sum_i \sum_m q_{im}(\theta^k) \log \pi_m + \sum_i \sum_m q_{im}(\theta^k) \log p_i(\beta_m) \quad (29)$$

where $\theta = (\beta_m, \pi_m)$

As π_m enters only in the first part and β_m only in the second part, the maximization can be done separately

$$\beta_m^{k+1} = \underset{\beta_m}{\operatorname{argmax}} \sum_i q_{im}(\theta^k) \log p_i(\beta_m) \quad (30)$$

$$\pi^{k+1} = \underset{\pi}{\operatorname{argmax}} \sum_i \sum_m q_{im}(\theta^k) \log \pi_m \quad (31)$$

The following are the steps to arrive at the optimum value θ^* that maximizes the likelihood of the data

1. Start with initial guess $\theta^1 = (\beta_m^1, \pi_m^1)$
2. Determine $q_{im}(\theta^k)$ at the current guess of θ^k as $q_{im}(\theta^k) = \frac{\pi_m^k p_i(\beta_m^k)}{\sum_m \pi_m^k p_i(\beta_m^k)}$

3. Perform the next iteration to determine θ^{k+1} as

$$\pi_m(\theta^{k+1}) = \frac{\sum_i q_{im}(\theta^k)}{\sum_m \sum_i q_{im}(\theta^k)} \quad (32)$$

$$\beta_m^{k+1} = \operatorname{argmax}_{\beta_m} \sum_i q_{im}(\theta^k) \log p_i(\beta_m) \quad (33)$$

4. Stop if $\|\theta^{k+1} - \theta^k\| < \text{tol}$. Otherwise, set $k = k + 1$ and repeat steps 2-4.

Appendix D: Algorithm to compute optimal prices

Discretize both w^m and o^m over n points between 0 and 1 where w^m indicates the percentage of Type- m people who have watched the movie and o^m that share of w^m who also own the movie. Let $S = (w^1, o^1, \dots, w^M, o^M)$ denote the state of the market.

1. Set the terminal period T at some large value. At each S compute the static prices $P(S, T) = P_{static}(S)$ and profits $\pi_{static}(S, T)$. Use these as the starting points in the dynamic optimization.

2. Given consumer and firm value functions at $t+1$ solve, by backward induction, for the consumer and firm value functions at t . At each S maximize the firm's objective function to determine the optimal prices $P(S, t)$.

Firm value function

$$W(S, t) = \max_{P(S, t)} \pi(S, t) + \delta W(S', t + 1 | S)$$

subject to the following constraints for each consumer-type m

$$V_{buy}(s < 3, S, t) = U_{buy}(s, S, t) + \delta \operatorname{E} \max_{s'} \left(\begin{array}{l} V_{consume}(s' = 3, S', t + 1 | s, S), \\ V_{notConsume}(s' = 3, S', t + 1 | s, S) \end{array} \right)$$

$$V_{rent}(s < 3, S, t) = U_{rent}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{c} V_{buy}(s' = 2, S', t + 1 | s, S), \\ V_{rent}(s' = 2, S', t + 1 | s, S), \\ V_{opt}(s' = 2, S', t + 1 | s, S) \end{array} \right)$$

$$V_{opt}(s < 3, S, t) = U_{opt}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{c} V_{buy}(s' = s, S', t + 1 | s, S), \\ V_{rent}(s' = s, S', t + 1 | s, S), \\ V_{opt}(s' = s, S', t + 1 | s, S) \end{array} \right)$$

$$V_{consume}(s = 3, S, t) = U_{consume}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{c} V_{consume}(s' = s, S', t + 1 | s, S), \\ V_{notConsume}(s' = s, S', t + 1 | s, S) \end{array} \right)$$

$$V_{notConsume}(s = 3, S, t) = U_{notConsume}(s, S, t) + \delta Emax_{\varepsilon'} \left(\begin{array}{c} V_{consume}(s' = s, S', t + 1 | s, S), \\ V_{notConsume}(s' = s, S', t + 1 | s, S) \end{array} \right)$$

where $S'|S$ is endogenous and $S' = [w', o']$ is given by

$$w' = w + (1 - w)(s_{buy}(s = 1, S, t) + s_{rent}(s = 1, S, t))$$

$$o' = \frac{w \cdot o + (1 - w)s_{buy}(s = 1, S, t) + w(1 - o)(s_{buy}(s = 2, S, t))}{w'}$$

Here

$s_{buy}(s, S, t)$, $s_{rent}(s, S, t)$ are computed using Equations 9 and 10

$Buy(S, t)$, $Rent(S, t)$ are given by Equations 11 and 12

$\pi(S, t)$ is given by Equation 15