The Effects of Price Discrimination on Copyright Duration

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Abstract

Copyright law is intimately related to price discrimination. Price discrimination in selling information products and services is commonplace and the practice may be posed to grow in the digitalized environment. However, price discrimination has yet to be incorporated into formal analysis of copyright. This paper investigates the effect of price discrimination on optimal copyright duration, information availability, and welfare through modeling and simulation. It is found that through serving additional low evaluation customers, price discrimination increases information availability and social welfare but may increase or decrease copyright protection; and through extracting surplus from high valuation customers, price discrimination reduces optimal copyright duration but may increase or decrease information availability and social welfare;

1. Introduction

Copyright law is intimately related to price discrimination. According to Wendy (1998), intellectual property's traditional Genesis tale is essentially one of enabling a creator to price discriminate. On the one side, copyright confers monopoly power on creators, giving them the necessary ability to price discriminate. On the other hand, copyright's first sale

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principle and fair use doctrine limit the ability of creators to price discriminate (Meurer, 2001).

Price discrimination is important in selling information products. In its simplest form, to price discriminate is to charge different customers different prices for the same products. Because information products have large fixed costs of creating the first copies but much smaller marginal costs of reproducing additional copies, pricing information products at marginal costs would cause creators unable to recover creative costs. Pricing information products according to their values to customers may be a more suitable alternative (Shapiro and Varian, 1990).

Several factors suggest that price discrimination may be even more important for digital information products. First, digitalization further reduces the marginal costs of information products, making cost-based pricing even more inappropriate and value-based pricing more desirable. Second, digitalization may reduce barriers of entry to the creative sector and intensify competition among creators. Increased competition may make it more necessary to price discriminate (Baumol and Swanson, 2003).

Third, information technology may increase creators' ability to price discriminate. Digitalization reduces the cost for creators to customize their products, to provide different versions of the same information products, and to bundle information products and services (Shapiro and Varian, 1998; Bakos and Brynjolfsson, 1999, 2000; Viswanathan And Anandalingam, 2005). Information technology allows sellers to collect more data about customers and to use the data to price their products (Ulph and Vulkan, 2000). Versioning, bundling, and pricing based on customer-specific information are all tactics of price discrimination. Furthermore, development of Digital Rights Management Systems based on Trusted Computing Technology has the potential to give creators much greater control on the usage of their products (Anderson, 2003), therefore, to greatly reduce the possibility of sharing, piracy, and arbitrage, and increase the ability of creators to price discriminate.

Fourth, the increasing practices of selling information as services instead of as products and selling information products through licensing and the weakening of first sale and fair use doctrines in copyright for digital information products reduce the possibility of arbitrage by consumers. They increase the ability for creators to price discriminate. For example, information products can be charged by per pay view. Software and databases are increasingly licensed and protected by licensing contracts. First sale principle, which allows buyers of legal copies of information products to resell these copies, has been suggested not to apply for digital information products (Hyde, 2001). All these developments restrict consumers' ability to arbitrage and, therefore, increase the ability of creators to price discriminate.

Price discrimination has not been incorporated into formal models of copyright, e.g. those of Landes and Posner (1989), Yoon (2002), and Yuan (2005). Price discrimination has been discussed qualitatively in the copyright literature. For example, in a comprehensive analysis on the topic, Meurer (2001) discussed the effects of copyright on price discrimination and the effect of price discrimination on welfare. There is a large economic literature on price discrimination. Many studies in the economic literature study topics such as a) the effect on prices, output, and welfare of price discrimination by monopolists as well as imperfect competitors; b) different forms of price discrimination; c) various devices used by discriminators to sort customers, e.g., consumer characteristics, coupon, bundling, versioning, timing, price-matching, etc., and d) price discrimination on markets where customers may be intermediate firms or final consumers (See surveys of the economic literature in Ekelund, 1970; Varian , 1989, and Stole, 2006).

This study attempts to measure the effects of price discrimination on optimal copyright duration, availability of first-copy information products, and social welfare. The effects are not obvious. For example, price discrimination has two opposite effects on optimal copyright duration. First, price discrimination allows creators to make more profits during copyright protection, therefore, gives more incentive for creators to create first-copy products. This reduces the need for lengthy copyright protection. Second, price discrimination may reduce the deadweight losses caused by the monopoly established by copyright. This reduces the need to shorten the length of copyright protection in order to control the deadweight losses. The overall effect of price discrimination depends on the relative magnitude of the two effects.

This paper models the effect of price discrimination on copyright duration by adding terms in the copyright model of Yuan (2005). The added terms represent the direct effects of price discrimination on creators' profits and consumer surplus. Price discrimination generally has three direct effects: Creators can a) extract surpluses from high evaluation consumers; b) develop new revenue sources by tapping otherwise un-served demand and low valuation customers; and c) by doing so, bring surplus to the low valuation customers. The paper studies how these three direct effects affect optimal copyright duration, information availability, and social welfare.

The main results of paper are: a) creators' serving otherwise un-served demand and low evaluation customers increases information availability and social welfare but may decrease or increase copyright duration; b) creators' extracting surplus from high evaluation consumers reduces optimal copyright duration but may increase or decrease information availability and social welfare.

The rest of paper is organized as follows: The next section develops the model; the section following the next section presents the results; the paper then concludes.

2. The Model

The model builds on Yuan (2005). As in Yuan (2005), creators create substitutive information products and sell copies to consumers. During copyright protection, each creator is the sole seller of its information products but competes with substitutes from other creators. Under monopolistic competition, creators price their products above marginal costs. Above marginal-cost pricing produces revenue for creators to recover creative costs but at the same time causes deadweight losses. In addition to Yuan (2005), creators can price discriminate. Price discrimination allows creators to further extract surpluses from high evaluation consumers and to serve otherwise un-satisfied demands and un-served low evaluation customers. As in Yuan (2005), after copyrights expire, anyone is free to copy the products. Information products will then be priced at marginal costs. Creators can not make revenue above marginal cost. Deadweight losses are avoided. Comparing fixed creative costs and the revenue earned beyond variable costs, each creator makes decisions on how many first-copy products to create and whether to enter/stay on the market. The copyright authority chooses copyright duration to maximize social welfare, which is the sum of surpluses of creators and consumers during and after copyright duration.

The following notations are used in the model:

n: number of creators in the market;

s_i: number of first-copy products of creator i, i=1, 2, …, n;

s_{-i}: vector of numbers of first-copy products of creators other than i;

p_{it}: price per copy (or per use) of each product of creator i at time t;

p_{-it}: vector of prices per copy (or per use) of products of creators other than i at time t;

$D_{it}(s_i, pit, s_{-i}, p_{-it}, t)$: the rate of demand per unit time for products of creator i at time t;

$c_i(s_i)$: the cost of creating s_i number of first-copy products of creator i;

b: the cost of reproducing and distributing a copy of any product of any creator;

γ: the discount rate of consumer surplus and creator profits;

T: duration of copyright protection;

λ: the proportion of deadweight losses recovered through price discrimination during copyright;

λ_1: share of recovered deadweight losses as profit by creators. $(1- \lambda_1)$ is then the share of recovered deadweight losses as surplus by consumers;

λ_2: proportion of surplus of high evaluation consumers extracted by creators through price discrimination.

$0\leq\lambda\leq1$, $0\leq \lambda_1\leq1$, and $0\leq\lambda_2\leq1$ describe the direct effects of price discrimination on creators and consumers. Customers can be divided into low evaluation customers and high evaluation customers. Low valuation customers are those who would not be served if price discrimination is not allowed. High evaluation customers are those who are served under no price discrimination. With price discrimination, low valuation customers either are indifferent or gain. High valuation customers either are indifferent or lose. Creators will not lose. Otherwise, they would not price discriminate (Meurer, 1997).

When λ=0 and λ_2=0, there is no price discrimination; when λ=1 and λ_2=1, there is perfect price discrimination, i.e., all surpluses are extracted by creators during copyright protection; when λ=0, price discrimination does not help serving un-satisfied demands and low evaluation customers; when λ=1, all low valuation customers whose evaluation is above marginal cost of copying are served and all deadweight losses are recovered; when λ_1=1, creators reap all recovered deadweight losses as profits. When λ_1=0, consumers enjoy all recovered deadweight losses as surplus.

In this study, the parameters λ, λ_1, λ_2 are exogenous; and the effects of different values of λ, λ_1, λ_2 on the copyright duration, information availability, and social welfare are investigated. One can start with the baseline situation where there is no price discrimination, i.e. λ=0 and λ_2=0, and then measure the differences in optimal copyright duration, information availability, and welfare from the baseline for different values of λ, λ_1, and λ_2.

If there is no price discrimination, the rate of revenue of creator i at time t is:

$$\pi^0{}_i = D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b).$$

The rate of deadweight loss is:

$$\int_b^{p_{it}} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp - D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)$$

When creators can price discriminate, a creator can lower prices to serve otherwise un-served demand, recovering deadweight losses, and can raise price for high valuation customers, extracting surplus from the high valuation customers. The rate of revenue of creator i at time t becomes:

$$\pi_{it} = D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b) +$$
$$\lambda\lambda_1 [\int_b^{p_{it}} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp - D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)]$$
$$+ \lambda_2 \int_{p_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp$$

The total revenue of creator i during copyright is:

$$\int_0^T D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)e^{-rt}dt +$$
$$\lambda\lambda_1 \int_0^T [\int_b^{p_{it}} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp - D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)]e^{-rt}dt$$
$$+ \lambda_2 \int_0^T \int_{p_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dpe^{-rt}dt$$

where first term is the revenue when there is no price discrimination; the second term is the share of the recovered deadweight losses of the creator; and the third term is the portion of surplus of high valuation customers extracted by the creator.

The profit of creator i is the revenue minus creative cost:

$$\Pi_i = \int_0^T D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)e^{-rt}dt +$$
$$\lambda\lambda_1 \int_0^T [\int_b^{p_{it}} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp - D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)]e^{-rt}dt,$$
$$+ \lambda_2 \int_0^T \int_{p_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dpe^{-rt}dt - c_i(s_i)$$

When there is no price discrimination, a creator chooses a single price for its products at a given time. This price is used to calculate the consumer surplus of high valuation customers and dead weight losses. This price is chosen by a creator to maximize the rate of net revenue under no price discrimination at each point of time:

$$\frac{\partial}{\partial p_{it}} \pi^{0}{}_{it} = 0 \tag{1}$$

Each creator chooses the number of its first-copy products to maximize its total profit with price discrimination:

$$\frac{\partial}{\partial s_i} \Pi_i = 0 \tag{2}$$

Finally, creators make entry decision. In equilibrium, the marginal creator makes zero economic profit:

$$\Pi_i = 0, \qquad \text{for i=n} \tag{3}$$

When all creators are assumed to have identical technology, they all make zero profit.

The copyright authority cares about social welfare. Social welfare includes creator profits and consumer surplus. Assuming identical creators, profits of creators are zero and social welfare is the same as consumer surplus. Consumer surplus can be divided into two parts: surplus after copyright protection and surplus during copyright protection. Consumer surplus during copyright protection equals the consumer surplus during copyright when there is no price discrimination adjusted by two factors. The first factor is the surplus extracted from high evaluation customers by creators; the other is the deadweight losses recovered and shared by the consumers. Therefore, social welfare can be written as:

$$L = \sum_{i=1}^{n} \int_{T}^{\infty} (\int_{b}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t) dp) e^{-\gamma t} dt$$
$$+ (1-\lambda_2) \sum_{i=1}^{n} \int_{0}^{T} (\int_{p^*_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t) dp) e^{-\gamma t} dt$$
$$+ (1-\lambda_1)\lambda [\sum_{i=1}^{n} \int_{0}^{T} (\int_{b}^{p^*_{it}} D_{it}(s_i, p, s_{-i}, p_{-it}, t) dp) e^{-\gamma t} dt - \sum_{i=1}^{n} \int_{0}^{T} D_{it}(s_i, p, s_{-i}, p_{-it}, t)(p^*_{it} - b) e^{-\gamma t} dt]$$

The first term is consumer surplus after copyright duration; second term is consumer surplus of high evaluation customers during copyright protection after the extraction of surplus by creators; the third term is the share of recovered deadweight losses by the consumers.

The problem of optimal duration is to choose T to maximize social welfare:

$$\underset{T}{Max} \quad \begin{aligned} L = & \sum_{i=1}^{n} \int_{T}^{\infty} (\int_{b}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t) dp) e^{-\gamma t} dt \\ & + (1-\lambda_2) \sum_{i=1}^{n} \int_{0}^{T} (\int_{p^*_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t) dp) e^{-\gamma t} dt \\ & + (1-\lambda_1)\lambda [\sum_{i=1}^{n} \int_{0}^{T} (\int_{b}^{p^*_{it}} D_{it} dp) e^{-\gamma t} dt - \sum_{i=1}^{n} \int_{0}^{T} D_{it}(p^*_{it} - b) e^{-\gamma t} dt] \end{aligned} \qquad (4)$$

Subject to (1-3).

3. Simulation Results

3.1 Specifications of Demand and Cost

Specific functions for demand $D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)$ and cost $c_i(s_i)$ are needed to solve the model. Following Yuan (2005), assume:

$$D_i(s_i, p_{it}, s_{-i}, p_{-it}, , t) = D_0 \left(s_i \middle/ \sum_{j=1}^{n} s_j \right) (\sum_{j=1}^{n} s_j)^{\alpha} p_i^{-\delta} \prod_{j \neq i} p_j^{\frac{\beta}{n-1}} g(t) \qquad (5)$$

$$\text{where } g(t) = \begin{cases} 1 - \frac{t}{T_0} & if \quad t < T_0(1-\theta) \\ \theta & otherwise \end{cases} \tag{6}$$

$$c_i(s) = c_0 + as^{\rho} \qquad \forall \text{ i} \tag{7}$$

where $0<\alpha<1$, $\delta>1$, $\beta>0$, $0\leq \theta <1$, $\rho>1$, and D_0, T_0, c_0, and a are positive constants.

The demand function (5) reflects how demand for a creator's products changes with its price, the prices of products of its competitors, and the number of its first-copy products and the number of first-copy products of its competitors. The factor $\left(\sum_{j=1}^{n} s_j\right)^{\alpha}$ in demand function (5) and $\alpha>0$ mean that the total demand for information increases with the total number of first-copy information products. The parameter α is the percentage increase in demand from a percentage increase in the number of first-copy products. $\alpha<1$ means that first-copy products are substitutes.

The factor $\prod_{j\neq i} p_j^{\frac{\beta}{n-1}}$ and positive β mean that demand for products of a creator increases with the prices of products of other creators. β is the cross-price elasticity. The factor $s_i \Big/ \sum_{j=1}^{n} s_j$ in (5) implies that total demand for information is distributed among creators in proportion to their numbers of first-copy products, other things being equal.

The parameter δ is the price elasticity of demand for a creator's products. The condition $\delta>1$ is necessary for consumer surplus to be finite. Note that demand D_i depends on p_{it} only through the factor $p_{it}^{-\delta}$ in (5). From (5) and constraints (1), one can derive:

$$p_{it} = p \equiv \frac{\delta}{\delta - 1} b \quad (8)$$

The factor g(t) represents the change in the demand level for copies of given information products over time. The specific form (6) assumes that the demand decreases linearly over time until the demand reduces to θ at time T_0*(1- θ) and then stays constant at that level.

In (5), all first-copy products are related to demand in the same way. In cost function (7), parameter c_0 represents the fixed cost of creation; parameter a is related to per-product development cost; and ρ>1 means that there are decreasing returns to scale in creation.

The above specifications assume that creators are symmetric: creators have identical creation, reproduction, and distribution costs and symmetric demand functions. Thus, in equilibrium, one can expect that each creator has the same size and charges the same price.

3.2 Results

Based on the above specific demand and cost functions, an explicit analytical solution is not found. Numerical method is used to compute the values for optimal duration T, number of first-copy products per creator s, number of creators n, and social welfare L for given values of the market parameters D_0, α, δ, β, b, T_0, θ, γ, c_0, a, ρ, λ, λ_1, and λ_2. The effects of changes in the parameters λ, λ_1, and λ_2 are then simulated.

First, assume there is no price discrimination, i.e., λ=0 and λ_2=0. When λ =0, λ_1 is inconsequential. Further assume the following values for the other parameters:

[D_0, α, δ, β, b, T_0, θ, γ, c_0, a, ρ] = [10^7 0.25 2 0.5 5 100 0.001 0.05 3*10^5 10^4 1.2].

Note that b=5 is the per-copy cost of reproduction and distribution; γ=0.05 is the discount rate; $D_0=10^7$ represents the general level of demand; $T_0=100$ and θ=0.001 indicate that demand decreases linearly to one thousandth of the initial demand in 99.9 years and then stay at that level; price elasticity δ is 2, and cross-price elasticity β is 0.5; and α=0.25 represents that different information products are assumed to be substitutes. These parameter values are not selected to represent an actual information market but to be in the economic valid ranges and to be changed.

With the above parameter values, solving the model results in T=19, n=122, s=63, p=10, and $L=0.5*10^9$. The optimality of the result is shown in Figure 1 and 2. Figure 1 shows that each creator makes zero profit at optimal size of 63 first-copy products, given that copyright duration is at the socially optimal 19 years. More or fewer than 63 first-copy products per creator cause creators to make negative profits. Figure 2 shows that copyright durations shorter or longer than 19 years cause loss in social welfare.

Figure 1 Optimal Creator Size

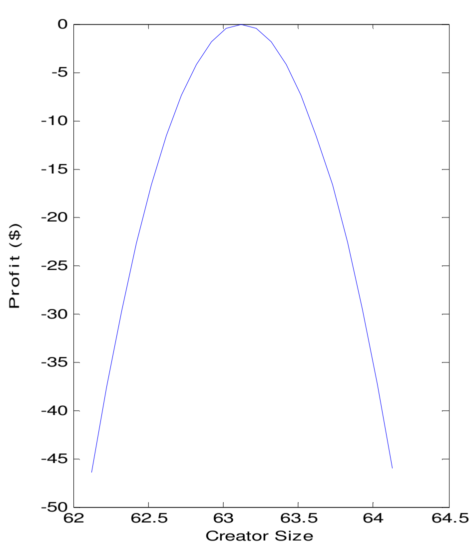
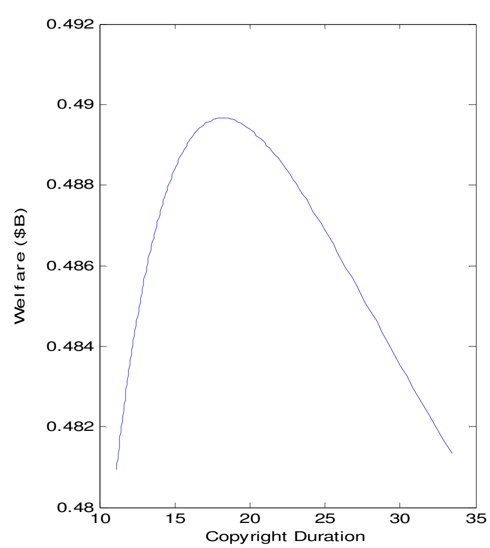


Figure 2. Optimal Copyright Duration



3.2.2 The Effect of Recovering Deadweight Losses by Serving Low Valuation Customers

More interesting is how optimal copyright duration, information availability, and social welfare change with price discrimination. Price discrimination enable creators to lower prices to serve otherwise un-served demands and low evaluation customers and, therefore, and recover deadweight losses. The recovered deadweight losses can be shared by the creators and consumers as profits and surpluses.

To investigate the effect of serving low valuation customers, choose and fix the values for λ_1 and λ_2 and other parameters and change the parameter λ. First, assume λ_2=0 and λ_1=1, i.e., there is no surplus extraction from high evaluation customers and all recovered deadweight losses are reaped by creators as profits; and draw a set of random values for the other parameters D_0, α, δ, β, b, T_0, θ, γ, c_0, a, and ρ; and change λ through 0 to 1, solve the model for each set of values of the parameters. Repeat the process for other randomly drawn sets of values for D_0, α, δ, β, b, T_0, θ, γ, c_0, a, and ρ. The values of these other parameters are drawn randomly from the following respective intervals 0-10^9; 0-1; 1-100; 0-10; 0.1-3000; 1 -1000; 0-1; 0-0.2; 1000-3*10^7; 10-10^6; and 1-10. These intervals cover all possible values for α and θ and wide ranges for the other parameters. We count only those random parameter values with which the model can be solved numerically at different values for λ. For all 129 solvable cases, optimal copyright duration is found to decrease with λ and the number of first-copy products per creators, number of creators, and social welfare all increase with λ.

Repeat the process for λ_2=0 and λ_1<1. It is found that the number of copyright products and social welfare always remain increasing with λ. However, as λ_1 decreases from 1 to zero, optimal copyright duration switches from decreasing with λ to increasing with increasing with λ.

In summary, creators' serving otherwise un-served demand and recovering deadweight loss increase information availability and social welfare. However, it may decrease or increase optimal copyright duration, depending on the share of creators and consumers of the recovered deadweight losses. If creators retain all the recovered deadweight losses, optimal copyright duration may decrease; if consumers share recovered deadweight losses as surplus, copyright duration may be increased.

The above results can be understood by considering the following. When creators reap deadweight losses as profit, it increases the incentive for creation and, therefore, reduces the need for lengthy copyright protection. When consumers share the recovered deadweight losses as surplus, it increases the value of information products to society and, therefore, calls for more information products to be created and more incentive for creation to be given and longer copyright duration to be set. The net effect on copyright duration depends on the relative magnitudes of the two opposite effects. When creators reap all the recovered deadweight losses as profits, the value of the information is increased the least; overall optimal copyright duration may decreases. When consumers get a relatively larger share of the recovered deadweight losses, the value of information products is increased more; longer copyright duration is desirable; overall optimal copyright duration may increase.

On the one hand, share by creators of recovered deadweight induces creators to create more products and induces more creators to the market. The creation of these additional products is financed by recovered deadweight loss and does not add cost to the society. Since consumers like variety, the new products bring net benefit to consumers. On the other hand, share by consumers of recovered deadweight are pure positive surplus to consumers, which increases the value of information products to society, calling for more products to be created. Therefore, recovered deadweight losses, regardless shared by creators or consumers, increase the number of first-copy information products and social welfare.

3.2.1 Effect of Extracting Surplus from High Valuation Consumers

Price discrimination is also used by creator to extract surpluses from high evaluation consumers. To investigate the effect of creators' extracting surplus from high evaluation consumers, we first fix parameters λ=0 and λ_1=0, and change value of parameter λ_2 through 0 to 1, and recalculate the model. This process is repeated for various random values for the other parameters D_0, α, δ, β, b, T_0, θ, γ, c_0, a, and ρ. For 397 usable random parameter values in our experiment, optimal copyright duration is found to decreases with λ_2. This suggests creators' extracting surpluses from high evaluation customers leads to shorter optimal copyright duration. However, for 285 out of the 397 cases, number of creators, number of first-copy products per creator, and social welfare decreases with λ_2; and for 112 out of the 397 cases they increases with λ_2. That is, creators' extracting surpluses from high evaluation customers may increases or decrease social welfare, depending on the market conditions described by the other market parameters.

It may be easy to understand why optimal copyright duration decreases when creators extract surpluses from high evaluation consumers during copyright duration. First, creators' extracting surpluses increases the incentive of creators to create first-copy products. Therefore, shorter copyright duration is needed to give sufficient incentive for creation.

Second, since creators make zero profits when entry is free in the creative sector, social welfare is the same as consumer surplus. Therefore, the more surpluses are extracted from consumers, the less valuable are information products to society for given length of copyright protection, which means that fewer information products are desirable. Therefore, shorter copyright protection is warranted to give incentive to create the less desired information products.

It may be less straight forward to understand why social welfare and information availability may sometimes increase and sometimes decrease when creators extract surpluses from high evaluation consumers. When creators extract surpluses from existing consumers, consumer surplus during copyright protection is reduced directly. However, consumer surplus after copyright duration is increased due to the increase in first-copy products and the shorter optimal copyright duration described above, which reduces deadweight losses. If the increase in consumer surplus after copyright duration is more than the decreases in consumer surplus during copyright protection, total social welfare will be increased and more first-copy information products should be created. If the increase in consumer surpluses after copyright duration is less than the decreases in consumer surplus during copyright protection, total social welfare will be decreased and fewer first-copy information products will be created.

When $\lambda=0$ and $\lambda_1=0$, i.e. no deadweight loss is recovered by price discrimination, increase in consumer surplus after copyright includes the reduced deadweight loss due to shorter optimal duration. It is possible that the increases in consumer surplus after copyright duration be more than the decrease in consumer surplus during copyright. Therefore, net social welfare may increase.

When λ=1 and λ_1=1, i.e., there is no deadweight loss. Increase in consumer surplus after copyright due to shorter optimal duration does not include a reduced deadweight loss. The increase in consumer surplus after copyright duration is less likely to be more than the decrease in consumer surplus during copyright. Net social welfare can decrease. Indeed, when λ=1 and λ_1=1, it is found that for all 373 solvable random values of D_0, α, δ, β, b, T_0, θ, γ, c_0, a, and ρ, extracting surplus from high evaluation customers reduces social welfare, information availability, and optimal duration of copyright.

It is likely that creators will price discriminate against both high valuation and low valuation customers at the same time. The results suggest that when deadweight losses are recovered, extracting surplus from high valuation customers will cause shorter optimal copyright duration and is also more likely to cause information availability and social welfare to fall. The effect of serving additional low evaluation customers interacts with the effect of extracting surplus from high evaluation customers.

4. Conclusion

We developed an approach to measure the effects of price discrimination on optimal copyright duration, information availability, and social welfare. Our results suggest that through its effect of serving otherwise un-served demand and low valuation customers, price discrimination increases information availability and social welfare but may increase or decrease optimal copyright duration; through its effect of extracting surplus from high valuation customers, price discrimination reduces optimal copyright duration but may increase or decrease information availability and social welfare.

The results suggest that public policy should encourage price discrimination against low-valuation consumers of information products. However, under such a policy, price discrimination against high valuation customers is likely to cause harm to social welfare and, therefore, should be discouraged. Since price discrimination is likely to benefit low valuation consumers, the results further suggest that optimal copyright duration may be increased if price discrimination against high valuation customers is prohibited.

Acknowledgement

This research is supported in part by a Roger Williams University Foundation 2006-2007 Research Grant.

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Appendix: Mathematical Procedures to Solve the Model

Without price discrimination, rate of revenue of creator i at time t is:

$$\pi^0{}_i = D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)$$

The non-discriminator price p_{it} is chosen at:

$$\frac{\partial}{\partial p_{it}} \pi^0{}_{it} = 0 \qquad \text{(A1)}$$

With price discriminate, the profit of creator i is:

$$\begin{aligned}\Pi_i &= \int_0^T D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)e^{-rt} dt + \\ &\int_0^T [\int_b^{p_{it}} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp - D_{it}(s_i, p_{it}, s_{-i}, p_{-it}, t)(p_{it} - b)]e^{-rt} dt\lambda\lambda_1\ , \\ &+ \lambda_2 \int_0^T \int_{p_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dpe^{-rt} dt - c_i(s_i)\end{aligned}$$

Each creator chooses number of its first-copy products to maximize its total profit:

$$\frac{\partial}{\partial s_i} \Pi_i = 0 \qquad \text{(A2)}$$

Due to free entry, the marginal creator makes zero profit in equilibrium:

$$\Pi_i = 0 \qquad \text{for i=n} \tag{A3}$$

When all creators have identical technology, they all make zero economic profit.

The problem of optimal duration is to choose T to maximize social welfare:

$$\begin{aligned} & L = \sum_{i=1}^{n}\int_{T}^{\infty}(\int_{b}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp)e^{-\gamma t}dt \\ \underset{T}{Max} \quad & +(1-\lambda_2)\sum_{i=1}^{n}\int_{0}^{T}(\int_{p^*_{it}}^{\infty} D_{it}(s_i, p, s_{-i}, p_{-it}, t)dp)e^{-\gamma t}dt \\ & +(1-\lambda_1)\lambda[\sum_{i=1}^{n}\int_{0}^{T}(\int_{b}^{p^*_{it}} D_{it}dp)e^{-\gamma t}dt - \sum_{i=1}^{n}\int_{0}^{T} D_{it}(p^*_{it}-b)e^{-\gamma t}dt] \end{aligned} \tag{A4}$$

subject to (A1-3).

Assume:

$$D_i(s_i, p_{it}, s_{-i}, p_{-it},, t) = D_0\left(s_i \Big/ \sum_{j=1}^{n} s_j \right)(\sum_{j=1}^{n} s_j)^{\alpha} p_i^{-\delta} \prod_{j\neq i} p_j^{\frac{\beta}{n-1}} g(t) \tag{A5}$$

$$\text{where } g(t) = \begin{cases} 1-\dfrac{t}{T_0} & if \quad t < T_0(1-\theta) \\ \theta & otherwise \end{cases} \tag{A6}$$

$$c_i(s) = c_0 + as^{\rho} \qquad \forall \text{ i} \tag{A7}$$

From (A5) and constraints (A1), one can derive:

$$p_{it} = p \equiv \frac{\delta}{\delta - 1} b \tag{A8}$$

Then (A5) becomes:

$$D_i(s_i, p_{it}, s_{-i}, p_{-it}, , t) = D_0\left(s_i \middle/ \sum_{j=1}^{n} s_j \right)(\sum_{j=1}^{n} s_j)^{\alpha} p_i^{-\delta} p^{\beta} g(t) \qquad \text{(A9)}$$

And profit of creator i becomes:

$$\begin{aligned}\Pi_i &= D_0 s_i (\sum_{j=1}^{n} s_j)^{\alpha-1} p^{-\delta+\beta}(p-b)G(T) + \\ &\lambda\lambda_1 D_0 s_i (\sum_{j=1}^{n} s_j)^{\alpha-1}[p^{\beta} \frac{1}{\delta-1}(b^{1-\delta} - p^{1-\delta}) - p^{-\delta+\beta}(p-b)]G(T) \qquad \text{(A10)} \\ &+ \lambda_2 D_0 s_i (\sum_{j=1}^{n} s_j)^{\alpha-1} p^{\beta} \frac{1}{\delta-1} p^{1-\delta} G(T) - c_i(s_i) = 0\end{aligned}$$

From (A3) $\Pi_i = 0$, one has

$$\begin{aligned}&D_0 s_i (\sum_{j=1}^{n} s_j)^{\alpha-1} p^{-\delta+\beta}(p-b)G(T) + \\ &\lambda\lambda_1 D_0 s_i (\sum_{j=1}^{n} s_j)^{\alpha-1}[p^{\beta} \frac{1}{\delta-1}(b^{1-\delta} - p^{1-\delta}) - p^{-\delta+\beta}(p-b)]G(T) \qquad \text{(A11)} \\ &+ \lambda_2 D_0 s_i (\sum_{j=1}^{n} s_j)^{\alpha-1} p^{\beta} \frac{1}{\delta-1} p^{1-\delta} G(T) = c_i(s_i)\end{aligned}$$

And

$$G(T) = \frac{c_i(s_i)}{D_0 s(ns)^{\alpha-1}\{p^{-\delta+\beta}(p-b) + \lambda\lambda_1[p^{\beta} \frac{1}{\delta-1}(b^{1-\delta} - p^{1-\delta}) - p^{-\delta+\beta}(p-b)] + \lambda_2 p^{\beta} \frac{1}{\delta-1} p^{1-\delta}\}} \qquad \text{(A12)}$$

From (A2) and (A11), one has:

$$\frac{\partial \Pi_i}{\partial s_i} = (\frac{1}{s_i} + \frac{\alpha - 1}{\sum_{j=1}^{n} s_j}) c_i(s_i) - c_i'(s_i) = 0 \qquad \text{(A13)}$$

By symmetry, $s_i = s_j = s$. From (A13), one has

$$n = \frac{1-\alpha}{1 - \frac{c'}{c}s} \qquad \text{(A14)}$$

Thus, n is a function of s. By (A14) and (A12), G(T) depends only on s.

Welfare function in (A4) becomes:

$$\begin{aligned} L &= D_0 (ns)^\alpha b^\beta \frac{b^{1-\delta}}{\delta - 1}[G(\infty) - G(T)] \\ &+ (1-\lambda_2) D_0 (ns)^\alpha p^\beta \frac{p^{1-\delta}}{\delta - 1} G(T) \\ &+ (1-\lambda_1)\lambda D_0 (ns)^\alpha [p^\beta \frac{b^{1-\delta} - p^{1-\delta}}{\delta - 1} - p^{-\delta+\beta}(p-b)] G(T) \end{aligned} \qquad \text{(A15)}$$

Through (A14) and (A12), L is only function of s. The first order condition is:

$$\begin{aligned} \frac{dL}{ds} &= D_0 (ns)^{\alpha-1} \alpha [n + s\frac{\partial n}{\partial s}] b^\beta \frac{b^{1-\delta}}{\delta - 1}[G(\infty) - G(T)] + D_0 (ns)^\alpha b^\beta \frac{b^{1-\delta}}{\delta - 1}[-\frac{\partial G}{\partial s}] \\ &+ (1-\lambda_2) D_0 (ns)^{\alpha-1} \alpha [n + s\frac{\partial n}{\partial s}] p^\beta \frac{p^{1-\delta}}{\delta - 1} G(T) + (1-\lambda_2) D_0 (ns)^\alpha p^\beta \frac{p^{1-\delta}}{\delta - 1}\frac{\partial G}{\partial s} \\ &+ (1-\lambda_1)\lambda D_0 (ns)^{\alpha-1} \alpha [n + s\frac{\partial n}{\partial s}][p^\beta \frac{b^{1-\delta} - p^{1-\delta}}{\delta - 1} - p^{-\delta+\beta}(p-b)] G(T) \\ & (1-\lambda_1)\lambda D_0 (ns)^\alpha [p^\beta \frac{b^{1-\delta} - p^{1-\delta}}{\delta - 1} - p^{-\delta+\beta}(p-b)] \frac{\partial G}{\partial s} = 0 \end{aligned}$$

(A16)

To numerically solve (A16), one needs first order derivative of (A16) to s:

$$
\begin{aligned}
&\frac{d^2L}{ds^2} = D_0\alpha(ns)^{\alpha-1}[2\frac{\partial n}{\partial s} + s\frac{\partial^2 n}{\partial s^2}]b^\beta \frac{b^{1-\delta}}{\delta-1}[G(\infty)-G(T)] \\
&D_0\alpha(\alpha-1)(ns)^{\alpha-2}[n + s\frac{\partial n}{\partial s}]^2 b^\beta \frac{b^{1-\delta}}{\delta-1}[G(\infty)-G(T)] \\
&D_0(ns)^{\alpha-1}\alpha[n + s\frac{\partial n}{\partial s}]b^\beta \frac{b^{1-\delta}}{\delta-1}[-\frac{\partial G}{\partial s}] \\
&+ D_0(ns)^{\alpha-1}\alpha[n + s\frac{\partial n}{\partial s}]b^\beta \frac{b^{1-\delta}}{\delta-1}[-\frac{\partial G}{\partial s}] \\
&+ D_0(ns)^{\alpha} b^\beta \frac{b^{1-\delta}}{\delta-1}[-\frac{\partial^2 G}{\partial s^2}] \\
&+ (1-\lambda_2)D_0(ns)^{\alpha-1}\alpha[2\frac{\partial n}{\partial s} + s\frac{\partial^2 n}{\partial s^2}]p^\beta \frac{p^{1-\delta}}{\delta-1}G(T) \\
&(1-\lambda_2)D_0\alpha(\alpha-1)(ns)^{\alpha-2}[n + s\frac{\partial n}{\partial s}]^2 p^\beta \frac{p^{1-\delta}}{\delta-1}G(T) \\
&(1-\lambda_2)D_0(ns)^{\alpha-1}\alpha[n + s\frac{\partial n}{\partial s}]p^\beta \frac{p^{1-\delta}}{\delta-1}\frac{\partial G}{\partial s} \\
&+ (1-\lambda_2)D_0(ns)^{\alpha-1}\alpha[n + s\frac{\partial n}{\partial s}]p^\beta \frac{p^{1-\delta}}{\delta-1}\frac{\partial G}{\partial s} \\
&(1-\lambda_2)D_0(ns)^{\alpha} p^\beta \frac{p^{1-\delta}}{\delta-1}\frac{\partial^2 G}{\partial s^2} \\
&+ (1-\lambda_1)\lambda D_0(ns)^{\alpha-1}\alpha[2\frac{\partial n}{\partial s} + s\frac{\partial^2 n}{\partial s^2}][p^\beta \frac{b^{1-\delta}-p^{1-\delta}}{\delta-1} - p^{-\delta+\beta}(p-b)]G(T) \\
&+ (1-\lambda_1)\lambda D_0\alpha(\alpha-1)(ns)^{\alpha-2}[n + s\frac{\partial n}{\partial s}]^2[p^\beta \frac{b^{1-\delta}-p^{1-\delta}}{\delta-1} - p^{-\delta+\beta}(p-b)]G(T) \qquad \text{(A17)} \\
&+ (1-\lambda_1)\lambda D_0(ns)^{\alpha-1}\alpha[n + s\frac{\partial n}{\partial s}][p^\beta \frac{b^{1-\delta}-p^{1-\delta}}{\delta-1} - p^{-\delta+\beta}(p-b)]\frac{\partial G}{\partial s} \\
&+ (1-\lambda_1)\lambda D_0(ns)^{\alpha-1}\alpha[n + s\frac{\partial n}{\partial s}][p^\beta \frac{b^{1-\delta}-p^{1-\delta}}{\delta-1} - p^{-\delta+\beta}(p-b)]\frac{\partial G}{\partial s} \\
&+ (1-\lambda_1)\lambda D_0(ns)^{\alpha}[p^\beta \frac{b^{1-\delta}-p^{1-\delta}}{\delta-1} - p^{-\delta+\beta}(p-b)]\frac{\partial^2 G}{\partial s^2}
\end{aligned}
$$

One can solve (A16) for s by Newton's Method. Then by (A14), (A12) and (A15), we can calculate n, T, and L.