PRICING UNDER THE THREAT OF PIRACY: FLEXIBILITY AND PLATFORMS FOR DIGITAL GOODS

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Pricing under the Threat of Piracy: Flexibility and Platforms for Digital Goods*

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Abstract

We consider the optimal design of flexible use in a digital-rights-management policy for a digital good subject to piracy. Consumers can acquire the digital good either as a licensed product or as an unlicensed copy. The ease of access to unlicensed copies is increasing in the flexibility accorded to licensed copies. The content provider has to trade off consumers' valuation of a licensed copy against the sales lost to piracy.

We enrich the basic model by introducing a "secure platform" that is required to use the digital good. We show that the platform allows for the socially optimal provision of flexibility for the digital good but only if both are sold by an integrated firm.

KEYWORDS: Digital Goods, Digital Rights Management, Platform, Flexibility, Piracy.

JEL CLASSIFICATION: C79, D42, L15.

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1 Introduction

The arrival of digital goods came with the promise of easy transferability and portability across various media and devices. In fact, for a user of digital goods, the corresponding flexibility is often an essential aspect of their valuation. Yet, for the provider of these goods, flexibility comes with the risk that unlicensed copies will circulate and undermine revenue-generating sales.

The objective of digital-rights-management (DRM) technologies is to enable the providers of digital goods to control the details of how consumers can use the goods. In many current DRM systems, the provider attempts to control the consumers' use of the good along several dimensions. Typical parameters include how long the consumer can use the good, how often he can use it, on how many devices he can use it simultaneously, and whether he can copy or alter it in any way.

In the current paper we aim to analyze the basic design of a DRM system as an optimal trade-off between the increase in the value of a licensed copy and the increase in the number of unlicensed copies. Intuitively, an increase in the allowed flexibility of a digital product increases the value of the product for its user and hence allows the seller to charge a higher price for a licensed copy. On the other hand, with an increase in flexibility comes the risk that a non-paying customer obtains, legally or not, access to the digital good. Hence an increase in flexibility may undermine sales volume. In addition, we study the role of a secure platform that is required to use the digital good. Such a platform allows the seller to extract extra rent and can therefore allow for a higher level of flexibility for the digital good. A key question therefore is whether the platform and the digital good are sold by separate firms or by an integrated firm.

We begin our analysis with a single content provider who offers a digital good to many consumers. The consumers have to choose between acquiring a licensed copy of the product and hoping to receive an unlicensed copy. The likelihood that the consumer is able to receive an unlicensed copy is increasing in the flexibility permitted by the DRM. The policy instruments of the content provider are price and permitted flexibility. An increase in the flexibility increases the revenue per item sold, but it also increases the likelihood that a given consumer obtains access to an unlicensed copy. The resulting equilibrium policies of the content provider attempt to find the optimal balance between flexibility and sales. In equilibrium, the consumers are divided into buyers of licensed products and consumers of unlicensed copies. The equilibrium volume of sales is determined endogenously by price and flexibility. An important determinant of the equilibrium policies is the rate at which licensed copies translate into access to unlicensed copies. In reality, this may depend on factors such as bandwidth of internet links, social connectedness, and other technological as well economic determinants. We show that in the absence of piracy, the provider chooses the socially efficient level of flexibility but reduces flexibility in response to an increasing threat of piracy.

In the case of online music sales, the most successful example is certainly Apple. It is currently by far the dominant provider of high quality digital-music files with its music store and playback software iTunes. Apple's success in selling music files is closely connected to its introduction of the portable music player iPod. In addition to having a significantly larger storage capacity than the previously common flash memories, the iPod also makes use of DRM technology. Only high quality files bought from Apple and those extracted from a user's own CDs using the iTunes software can be played by an iPod.[1] Conversely, the high-quality files from Apple's iTunes store can only be played on its own devices. The software and hardware provided by Apple clearly represent complementary products to the digital good. In the specific case of iTunes and iPods, they represent a platform for the use of the digital good that enhances the value of that good. At the same time, the digital goods sold by Apple can be used only on the platform provided by Apple. The platform thus achieves two objectives for Apple. It enhances the security of the DRM system itself, but it also restricts the use of unlicensed copies. Even the unlicensed copies can essentially only be used on the Apple platform. As a result, Apple as the platform provider can realize revenue from two sources: the sales of the music files and the sale of the platform (i.e. the hardware and associated software).

We therefore investigate the role of a platform in the context of DRM. We assume that, although the digital good may be acquired in the form of an unlicensed

[1] The iPod also plays low quality files as MP3 which certainly are no perfect substitutes for high quality files.

copy, it still has to run on the platform. This assumption completely removes concern about the security of the platform, but the essential part of the argument only requires that the platform be less susceptible to an unlicensed use than the digital good itself.

We then compare the outcomes of two polar cases, assuming first that separate firms sell the digital good and the platform and then that an integrated firm sells both. The analysis of two separate firms shows that there is a natural conflict between the owner of the rights to the digital good and the owner of the rights to the platform. The owner of the digital good would like to increase the revenue-generating sales of the good. For this reason, the content provider seeks to reduce the flexibility and increase the price. On the other hand, the platform provider cares less about the revenue coming from the sales of the digital good and more about the perceived value of the platform. He therefore wants to increase the flexibility of the DRM system, thus increasing the number of circulating copies of the digital good, licensed or not, in order to sustain the market for the platform. We show that the resulting equilibrium leads to a low level of flexibility, a high price of the digital good and a low price for the platform.

Next we analyze the case of a single provider that sells both a platform for his digital content and the content itself. The products are offered jointly but priced separately. We show that the joint provider who also sells a platform finds it optimal to provide each user with the socially efficient level of flexibility, in contrast to the provider who doesn't sell a platform and constrains flexibility. In addition, the price of the digital good itself is lower than before, even considering the higher level of flexibility. However, the joint provider is less concerned about the unlicensed segment of the market, because he can recover part of the surplus that arises due to the availability of unlicensed access through revenue from the sale of the platform itself. Consequently, the price of the platform serves the same function as an entrance fee to an amusement park. Because the content provider cannot extract all the surplus in the market for digital goods, he leaves surplus to the consumers. Thus, he can charge a substantial price for the platform that gives the consumers access to the market for digital goods. In fact, we show that the joint provider charges a higher price for the platform than the platform provider in the case of separate firms. Note that this is a novel business model that contrasts with the model employed in other markets of complementary goods in which customers make a one-time purchase of a device and then make recurring purchases of items that complement the device or subscribe to a complementary service. For example, Gillette makes money by selling blades not razors, and integrated communications companies make money by signing up cell-phone subscribers rather than by selling phones.

The development of Apple's use of DRM since its entry into the digital music market strongly resembles the findings of our model. Initially, under the iTunes DRM rules, flexibility was rather limited. Each music file could be played on only five devices at the same time that had to be authorized by the buyer of the file. Playlists, i.e. specific arrangement of several files, could only be burned to CDs seven times (see the standard restrictions in Apple (2011)). At the time Apple as the provider of the platform was in a relatively weak position when negotiating with the music industry who owned the rights to the digital music files. These early negotiations were characterized by the conflict between separate content provider and platform provider predicted by our model. In fact, the Financial Times quotes a music industry insider as saying "Our music is not something to be given away to sell iPods." (Financial Times, 2/2/2005).

By 2008 Apple had become the dominant player in the market for digital music with a significantly increased bargaining position with the music industry, moving the situation closer to our assumption of a joint provider.[2] In 2007 Apple started a public push for the sale of files without DRM restrictions resulting in agreements with some record labels to sell DRM-free files at higher prices (Apple (2007)). By April of 2009 all music sold on iTunes was available without DRM restrictions (Apple (2009)). In contrast, in markets for digital goods where Apple does not have a dominant platform such as TV shows and movies, the files are still only sold with severe DRM restrictions (Apple (2011)).

Related Literature. Several authors have put forth arguments about why piracy of easily reproducible goods might be beneficial to providers as well as consumers, thus adding new aspects to the discussion about copyright protection. Liebowitz (1985) was the first to show that, when each good is shared by a defined

[2] In April 2008 the iTunes Store became the top music retailer in the U.S. (Apple (2008)).

group of consumers (also called a "club"), the provider can indirectly appropriate revenues from all members of the group by charging a higher price. Varian (2000) finds that piracy in groups can be beneficial to the provider if sharing is cheaper than producing additional units, or if it enables price discrimination based on consumers' different valuations. Bakos, Brynjolfsson, and Lichtman (1999) emphasize that selling to groups may reduce demand uncertainty (just as bundling reduces it) and thus enable more profitable pricing. Parker and van Alstyne (2005) consider the pricing of complementary products in a model of two-sided markets. In our model, the complementary products, content and platform, are offered in a single market.

Dropping the assumption of sharing in defined groups, Conner and Rumelt (1991) and Takeyama (1994) show that piracy can increase profits if the good exhibits a positive network externality. Because piracy expands the user base, thus increasing the value of the good, the provider can charge buyers higher prices than he could without piracy. Sundararajan (2004) considers the role of digital management to restrict digital piracy in the context of an optimal pricing model. In his model, the possibility of piracy acts as a constraint on the pricing policy, but there is no interaction between the level of flexibility and the implicit cost of piracy in terms of foregone sales. Regarding illegal online sharing of music, recent empirical studies by Oberholzer-Gee and Strumpf (2007) and Rob and Waldfogel (2004) show a very limited effect of piracy on legal music sales.

2 Model

The digital good is demanded by a continuum of consumers on the unit interval $[0, 1]$. The gross utility of consumer i from a digital good is given by

$$\theta_i u(\lambda).$$

The valuation θ_i represents the willingness to pay for the digital good, whereas $\lambda \in [0, 1]$ represents the flexibility with which the digital good can be used by the consumer. The utility for flexibility $u(\lambda)$ is increasing and strictly concave with $u'(\lambda) \to \infty$ for $\lambda \to 0$ and $u'(1) = 0$. For simplicity, we shall assume that $\theta_i = i$

and that the consumers are uniformly distributed on the unit interval.

The seller of the digital good determines the price p and the level of flexibility λ at which the digital goods are sold to the consumers. The level of flexibility λ is the key choice variable in the seller's DRM design. For simplicity, we shall assume that the marginal cost of increasing flexibility is constant and equal to zero.[3] The revenue of the seller is given by the product of the price p and the sold quantity $q \in [0, 1]$. With zero marginal cost, net profit is equal to the revenue, i.e.

$$\Pi (p, q) = pq.$$

Each consumer i can purchase the digital good at the offered price p and flexibility λ. The net utility of a purchase for consumer i is then

$$\theta_i u (\lambda) - p.$$

We refer to the digital good that is purchased from the seller as a *licensed product*.

In the presence of a "greynet,"a potential buyer can alternatively attempt to obtain the digital good unlicensed as a *pirated copy*. However, a consumer who doesn't buy the digital good cannot be certain of receiving a pirated copy. Instead, a pirating consumer receives a copy only with a probability $\pi (\alpha, \lambda) \in [0, 1]$ so that the expected utility for consumer i of pirating is

$$\pi (\alpha, \lambda) \theta_i u (\lambda) .$$

For simplicity we assume that $\pi (\alpha, \lambda) = \alpha\lambda$. The key idea is that the probability of receiving an pirated copy is increasing in the flexibility λ with which the licensed versions are sold. The parameter $\alpha \in [0, 1]$ represents an exogenous access rate to digital goods and characterizes the permeability of the content-distribution environment, not the good itself. We consider α to capture both technical and non-technical factors, so increased permeability can result, e.g., from factors such as

[3] In the case of digital goods, the assumption of low marginal costs appears to be rather innocuous. We should point out, however, that, in the presence of DRM technology, there is a sense in which the cost of providing flexibility may not be constant or even monotone increasing. It might be most difficult technically to support intermediate levels of flexibility; very lenient or very strict DRM rules may be easier to implement.

higher internet bandwidth or contact frequency among consumers, or from more lenient copyright laws or less vigilant enforcement of existing copyright laws. The probability of obtaining a pirated copy is therefore increasing both in the flexibility λ of the digital good itself as well in the permeability α of the environment. Finally, we assume that flexibility and permeability are complementary since

$$\frac{\partial^2 \pi(\alpha, \lambda)}{\partial \alpha \partial \lambda} > 0,$$

that is a higher level of permeability doesn't reduce the effect of flexibility and vice versa.

In Section 4, we introduce the possibility of a platform in the form of a hardware device, a secure application program, or a secure hardware-software combination that is the only environment in which the content can be consumed. In this case, there will be an additional product that the consumers need to acquire in order to be able to realize the utility from the digital goods. Yet, this will not affect the basic elements of demand for digital goods presented in the model.

3 The Price of Flexibility

For a given flexibility λ and price p set by the provider of the digital good, the consumer i decides to purchase a licensed copy if his net utility from a purchase is greater than his expected utility from pirating:

$$\theta_i u(\lambda) - p \geq \alpha\lambda\theta_i u(\lambda).$$

The marginal buyer with valuation $\overline{\theta}$ is exactly indifferent between buying and pirating, and $\overline{\theta}$ is given by:

$$\overline{\theta} = \frac{p}{(1-\alpha\lambda)\, u(\lambda)}.$$

Since all consumers with valuation $\theta_i \geq \overline{\theta}$ are buyers, the provider faces a demand function for licensed copies of

$$q(p,\lambda) = 1 - \frac{p}{(1-\alpha\lambda)\,u(\lambda)}. \tag{1}$$

The demand for the digital good is decreasing in p as would be expected. The interesting comparative static is the impact of the choice of flexibility λ on demand.

Proposition 1 (Flexibility and Piracy)

1. *In the absence of any piracy threat, $\alpha = 0$, the demand is strictly increasing in the level of flexibility λ.*
2. *With the threat of piracy, $\alpha > 0$, demand is single-peaked in the level of flexibility λ, initially increasing but then decreasing.*

The proofs of all the results are relegated to the appendix. The fact that with the possibility of piracy the demand is single-peaked captures the key trade-off facing the seller of digital goods when deciding about the level of flexibility in his DRM design. An increase in flexibility leads to a higher value of the product for the consumers which has a positive effect on demand. Yet, at the same time the increase in flexibility leads to a higher likelihood of obtaining a pirated copy which has a negative effect on demand. Initially the increase in utility more than offsets the piracy threat and demand increases with flexibility, but since the marginal utility of any single consumer for flexibility is decreasing, it is ultimately dominated by the easy access to pirated copies and leads to lower demand.

The revenue of the provider depends on the charged price p and the allowed flexibility λ, with:

$$\Pi(p,q) = pq(p,\lambda). \tag{2}$$

Maximizing this profit over p and λ leads to the following proposition.

Proposition 2 (Optimal Choice of Flexibility)

1. *For* $\alpha = 0$*, the provider chooses the efficient level of flexibility* $\lambda_0^* = 1$ *and sells the digital good at a price of* $p_0^* = \frac{1}{2}u(1)$*.*

2. *For* $\alpha > 0$*, the provider sets flexibility to* $\lambda^* < 1$ *implicitly defined by*

$$(1 - \alpha\lambda^*)\, u'(\lambda^*) - \alpha u(\lambda^*) = 0$$

and sells the digital good at a price of $p^* = \frac{1}{2}(1 - \alpha\lambda^*)\, u(\lambda^*)$*.*

3. *The optimal level of flexibility* λ^**, the optimal price* p^* *and the provider's profit are decreasing in the threat of piracy* α*.*

Without the threat of piracy the provider acts like a standard monopolist and sets the flexibility at the highest possible level since it comes at zero cost. Once the threat of piracy appears and α increases from zero, flexibility comes at a cost of decreased sales. Therefore the provider cuts back flexibility to reduce the probability of consumers obtaining a pirated copy to the point where the positive effect on demand is offset by the negative effect. Since the lower flexibility also reduces the utility buyers of licensed copies receive from the digital good, the provider also has to reduce the price. The higher the threat of piracy α, the more the provider cuts flexibility and price and the lower are his profits.

4 Platform and Flexibility

In the presence of the "greynet," the provider – even though a monopolist – is constrained in capturing the utility that the consumers derive from the digital good. Because every consumer can always try to obtain unlicensed copies instead of buying licensed ones, the provider is forced by this outside option to leave an extra rent to all consumers. The provider of the digital good therefore faces the problem of recovering the residual surplus from the consumer. A feasible and common strategy in digital-content distribution is the provision of a platform on which to use the digital good. In the current section, we therefore introduce a second product, a platform that is required in order to use the digital good. In the case of digital audio files, the immediate examples include digital music players such as Apple's iPod.

In economic terms, the platform constitutes a complimentary product to the digital good. In the presence of a platform, even the consumers who own unlicensed copies of the digital good have to buy the platform to consume the digital good. In other words, the platform does not create any additional value for the buyer over and above the consumption of the digital good. It simply represents a gatekeeper to the digital good. The platform owner can now recover some of the rent that the buyers obtained in the market for digital goods.

We denote by r the price of the platform. Now the utility consumer i receives from purchasing a licensed copy is given by

$$\theta_i u(\lambda) - p - r$$

and the utility consumer i receives from pirating the digital good is given by[4]

$$\alpha\lambda\theta_i u(\lambda) - r.$$

Conditional on purchasing the platform, the marginal buyer of the digital good with valuation $\overline{\theta}$ is indifferent between buying and pirating, thus $\overline{\theta}$ is given as before:

$$\overline{\theta} = \frac{p}{(1-\alpha\lambda)\, u(\lambda)}.$$

In addition, we now have to specify the marginal buyer of the platform with valuation $\underline{\theta}$. If the marginal buyer of the platform is a consumer who plans to pirate the digital good, he is indifferent between purchasing the platform and not participating in the market at all

$$\alpha\lambda\bar{\theta}u(\lambda) - r = 0.$$

[4] We assume that consumers who choose to pirate have to purchase the platform before they know if they will obtain an unlicensed copy.

The marginal buyer of the platform is therefore given by

$$\underline{\theta} = \frac{r}{\alpha\lambda u(\lambda)}.$$

All consumers with $\theta_i \geq \underline{\theta}$ purchase the platform and among these, all consumers with $\theta_i \geq \overline{\theta}$ purchase licensed copies of the digital good so the demand function for the platform $Q(r,\lambda)$ and the demand function for the digital good are simply:

$$Q(r,\lambda) = 1 - \frac{r}{\alpha\lambda u(\lambda)},$$
$$q(p,\lambda) = 1 - \frac{p}{(1-\alpha\lambda)u(\lambda)}.$$

The demand for the digital good is as before, decreasing in its price p and single peaked in its level of flexibility λ. The demand for the platform is also decreasing in its price r. In addition, however, it is strictly increasing in the flexibility λ of the digital good. We see that while a higher level of flexibility has an ambiguous effect on the demand for the digital good itself, it has a strictly positive effect on the demand for the platform.

4.1 Separate Firms

We first analyze the role of the platform in the context where the property rights to the platform technology and to the digital good are in the hands of separate firms. In this case, a classic conflict arises between the platform provider and the content provider. In the case of separate providers, the provider of the digital good chooses his price p and flexibility λ to solve

$$\max_{p,\lambda} pq(p,\lambda),$$

while the provider of the platform chooses only his price r to solve

$$\max_{r} rQ(r,\lambda).$$

This leads to the following proposition.

Proposition 3 (Separate Firms) *If the digital good and the platform are sold by separate firms, then*

1. *the provider of the digital good sets flexibility* $\lambda^* \leq 1$ *and selling the digital good at* $p^* = \frac{1}{2}(1 - \alpha\lambda^*)\, u(\lambda^*)$*;*

2. *the provider of the platform takes sells the platform at* $r^* = \frac{1}{2}\alpha\lambda^* u(\lambda^*)$*.*

Thus, in the presence of separate firms, the digital content provider behaves as in Proposition 2. Since the provider of the digital good doesn't take into account the effect his choice of flexibility has on the demand for the platform he behaves in the same way as if there were no platform. He chooses the level of flexibility that maximizes legal demand and then sets the monopolist price. The provider of the platform simply reacts to the level of flexibility chosen by the digital-good provider and sets his own price in accordance. While increasing flexibility has a purely positive effect on the profit of the platform provider (because it increases the value of access to the digital good), the digital-good provider faces the trade-off between increasing the value of licensed copies and restricting the availability of unlicensed ones.

4.2 Integrated Firm

We now analyze the role of the platform in the context of a single firm that sells both the digital good and the platform. In other words, the seller has the property rights and controls the prices of the digital content as well as the platform. In this case the joint provider chooses price p and flexibility λ for the digital good and price r for the platform to solve

$$\max_{p,r,\lambda} \left\{ pq(p,\lambda) + rQ(r,\lambda) \right\}.$$

This leads to the following proposition.

Proposition 4 (Integrated Firm) *If the digital good and the platform are sold by an integrated firm, then*

1. *the joint provider chooses the efficient level of flexibility* $\lambda^{**} = 1$*, regardless the threat of piracy* α*;*

2. *the price charged for the digital good is* $p^{**} = \frac{1}{2}(1-\alpha)\,u(1)$ *with* $p^{**} < p^{*}$*;*

3. *the platform is sold at a price* $r^{**} = \frac{1}{2}\alpha u(1)$ *with* $r^{**} > r^{*}$*.*

The joint provider fully takes into account the effect of the digital good's flexibility on the demand for the good itself and on the demand for the platform. When increasing the level of flexibility beyond λ^{*} the provider loses sales of licensed copies to easier piracy. To recoup the lost sales the provider reduces the price below p^{*} so he ends up offering a higher level of flexibility at a lower price. He can afford to do so because at the same time he sells the platform at a higher price. Since flexibility is socially costless but valuable the provider maximizes total welfare by setting flexibility at the efficient level and extracting the additional rent from consumers through platform sales.

4.3 Distribution Multiplier

Finally, we consider the implications of allowing the probability π of receiving a pirated copy of the digital good to depend also on the number of legal copies in distribution:

$$\pi(\alpha, \lambda, q) = \alpha\lambda q.$$

This implies that there is a distribution multiplier: the more legal copies are in circulation, the easier it is to gain access to a pirated version of the digital good. The multiplicative structure implies that the quantity q is complementary to both the flexibility λ of the digital good and the permeability α of the content-distribution environment. In the presence of the distribution multiplier, the demand is not linear anymore in the price as in (1). In turn, the content provider does not necessarily want to sell to a constant proportion of the market anymore as it was previously the case.

In fact, with separate firms, the equilibrium structure will display an increase in the segmentation across consumers. There will be low valuation consumers with valuations such that $\theta \in [0, \underline{\theta})$ who don't purchase the platform and a fortiori don't purchase the licensed digital content; there will be medium valuation customers with valuations $\theta \in [\underline{\theta}, \overline{\theta})$ whon only buy the platform but access the digital content in the unlicensed format and finally high valuation customer $\theta \in [\overline{\theta}, 1]$ who buy both the platform and the digital good.

Consumer i's net utility from purchasing a legal copy of the digital good remains unchanged,

$$\theta_i u(\lambda) - p,$$

but the expected utility of using pirates copies is now given by

$$\alpha \lambda q \theta_i u(\lambda).$$

The marginal buyer of the digital good who is exactly indifferent between buying and pirating now has a valuation $\overline{\theta}$ which depends on the quantity q,

$$\overline{\theta} = \frac{p}{(1 - \alpha\lambda q) u(\lambda)}.$$

Since the quantity demanded satisfies $q = 1 - \overline{\theta}$ this implies that demand is the root of a quadratic equation and is given by

$$q^*(p, \lambda) = \frac{(1 + \alpha\lambda) u(\lambda) - \sqrt{(1 + \alpha\lambda)^2 u(\lambda)^2 - 4\alpha\lambda u(\lambda)(u(\lambda) - p)}}{2\alpha\lambda u(\lambda)}.$$

Put together, this implies that $\underline{\theta} < \overline{\theta}$ and consumers are partitioned based on their valuation such that $\theta \in [0, \underline{\theta})$ don't buy anything, $\theta \in [\underline{\theta}, \overline{\theta})$ only buy the platform and $\theta \in [\overline{\theta}, 1]$ buy platform and digital good.The key properties, and the associated calculus of the previous propositions remain unaffected by this complication but the distribution multiplier leads to the following additional effects.

Proposition 5 (Distribution Multiplier) *The digital-good provider lowers sales to* $q^* < \frac{1}{2}$*. In the presence of a separate platform provider this leads to a partition of consumers:*

1. *low valuation consumers don't participate in the market;*
2. *medium valuation consumers buy the platform but pirate the digital good;*
3. *high valuation consumers buy the platform and the digital good.*

By contrast, we observe that in the presence of an integrated firm, the integrated firm charges a sufficiently high price for the platform, *and* the digital content is offered at a price sufficiently low, such that the observed additional segmentation with separate firms will not arise. In other words, all the consumers who have already purchased the platform at a substantial price, are now willing to pay the incremental price to access the digital good for sure rather than accepting the expected utility associated with a pirated copy.

5 Conclusion

In this paper, we provide a simple analysis of the role flexibility and platform play in digital rights management. The basic model shows that the optimal use of flexibility displays an important trade-off between providing a higher value to paying customers and increasing the likelihood of distribution through channels other than legitimate sales. We then show that a platform for the digital goods may lead to a socially beneficial improvement in the design of the flexibility rules if digital good and platform are owned by the same seller. However, if digital good and platform are complementary goods, but offered and priced by different sellers, then a conflict over the optimal flexibility rule emerges.

Our basic model had a number of simplifying features. Clearly, the analysis will have to be extended to better understand the emerging market structure and security provisions for digital goods. In many instances, content is available in many forms. Music, for example, is distributed through radio, TV, CDs, and digital copying. Because the demand for music in each market segment interacts with the other segments, the distribution and management policies will naturally be dependent on the structure of the other market segments. We began with a single provider and a single platform, and it is logical to ask how DRM would be affected by competing providers and platforms.

On the demand side, it seems natural to think about the intensity of demand for digital goods and the ease with which unlicensed copies can be obtained. The music industry's concern about file sharing by students in college dormitories clearly arises in part from the fact that their best customers in terms of sales volume are the ones that have the best technology for accessing unlicensed copies.

Finally, as soon as flexibility becomes an issue, more sophisticated pricing strategies seem natural. In this paper, we focused on the single-file pricing policy, but other plans are clearly being used or conceived to find an optimal trade-off. For example, monthly fees for limited or unlimited access to databases of music files are alternatives to single-file transactions.

Appendix

Proof of Proposition 1. For $\alpha = 0$ the expression for $q(p, \lambda)$ in (1) simplifies to $q(p, \lambda) = 1 - p/u(\lambda)$ which is decreasing in λ. For $\alpha > 0$, differentiating $q(p, \lambda)$ from (1) we get

$$\frac{\partial q(p, \lambda)}{\partial \lambda} = p\frac{(1 - \alpha\lambda) u'(\lambda) - \alpha u(\lambda)}{(1 - \alpha\lambda)^2 u(\lambda)^2}.$$

Since u is increasing and concave, for small values of λ the term $(1 - \alpha\lambda) u'(\lambda)$ is big and the term $\alpha u(\lambda)$ is small so that $\partial q(p, \lambda) / \partial \lambda > 0$. As λ increases the first term decreases and the second increases, eventually leading to $\partial q(p, \lambda) / \partial \lambda < 0$.

□

Proof of Proposition 2. Maximizing profit given by (2), the first order condition with respect to λ is given by

$$p^2 \frac{(1 - \alpha\lambda) u'(\lambda) - \alpha u(\lambda)}{(1 - \alpha\lambda^*)^2 u(\lambda^*)^2} = 0 \;\Rightarrow (1 - \alpha\lambda^*) u'(\lambda^*) - \alpha u(\lambda^*) = 0. \tag{3}$$

The first order condition with respect to p yields

$$1 - 2\frac{p}{(1 - \alpha\lambda) u(\lambda)} = 0 \quad \Rightarrow p^* = \frac{1}{2}(1 - \alpha\lambda^*) u(\lambda^*). \tag{4}$$

which results in a demand of $q(p^*, \lambda^*) = 1/2$. For $\alpha = 0$, equation (3) simplifies to $u'(\lambda^*) = 0$ which implies $\lambda_0^* = 1$ and therefore $p_0^* = \frac{1}{2}u(1)$ from equation (4). For $\alpha > 0$, implicit differentiation of (3) gives us the comparative static of λ^* with respect to α,

$$\frac{d\lambda^*}{d\alpha} = \frac{\lambda^* u'(\lambda^*) + u(\lambda^*)}{(1 - \alpha\lambda^*) u''(\lambda^*) - 2\alpha u'(\lambda^*)} < 0,$$

so $\lambda^* < 1$ and decreasing in α. Differentiating (4) using the envelope theorem we get

$$\frac{dp^*}{d\alpha} = -\frac{1}{2}\lambda^* u(\lambda^*) < 0.$$

Finally, this implies for the provider's profit

$$\frac{d\Pi(p^*, \lambda^*)}{d\alpha} = \frac{1}{2}\frac{dp^*}{d\alpha} < 0.$$

□

Proof of Proposition 3. The provider of the digital good faces the same problem as before, resulting in the first order conditions (3) and (4). The provider of the platform has a first order condition with respect to r given by

$$1 - 2\frac{r}{\alpha\lambda u(\lambda)} = 0. \tag{5}$$

Given the equilibrium level of flexibility λ^* this results in

$$r^* = \frac{1}{2}\alpha\lambda^* u(\lambda^*).$$

□

Proof of Proposition 4. Differentiating the joint provider's profit with respect to p and r yields the same first order conditions as (4) and (5) respectively and therefore

$$p^{**} = \frac{1}{2}u(\lambda^{**})(1 - \alpha\lambda^{**}), \quad r^{**} = \frac{1}{2}\alpha\lambda^{**}u(\lambda^{**}).$$

Differentiating the joint provider's profit with respect to λ we get the first order condition

$$p^2\frac{(1-\alpha\lambda)u'(\lambda) - \alpha u(\lambda)}{(1-\alpha\lambda)^2 u(\lambda)^2} + r^2\frac{\alpha\lambda u'(\lambda) + \alpha u(\lambda)}{(\alpha\lambda)^2 u(\lambda)^2} = 0. \tag{6}$$

Substituting in the expressions for p^{**} and r^{**} the condition simplifies to $u'(\lambda) = 0$, which implies the efficient level of flexibility $\lambda^{**} = 1$. The expression for p^{**} is maximized at λ^* given by (3) so it has to be lower for λ^{**} and therefore $p^{**} < p^*$. The expression for r^{**} is increasing in λ so it has to be higher for λ^{**} and therefore $r^{**} > r^*$. □

Proof of Proposition 5. Using the inverse demand the digital-good provider maximizes

$$qp(q,\lambda) = q(1-q)(1-\alpha\lambda q)u(\lambda).$$

Differentiating with respect to q we get

$$u(\lambda)((1-q)(1-\alpha\lambda q) - q(1-\alpha\lambda q) - \alpha\lambda q(1-q)) = 0$$

which implies an optimal quantity:

$$q^* < \frac{1}{2}.$$

With the distribution multiplier the marginal platform buyer changes slightly to

$$\underline{\theta} = \frac{r}{\alpha \lambda q u (\lambda)}.$$

A separate platform provider takes p, q and λ as given and maximizes

$$rQ(r, \lambda) = r\left(1 - \frac{r}{\alpha \lambda q u (\lambda)}\right),$$

which implies a price of $r = \frac{1}{2}\alpha\lambda q u(\lambda)$ and the quantity $Q = \frac{1}{2}$ as before. Put together, this implies that $\underline{\theta} < \overline{\theta}$ and consumers are partitioned based on their valuation such that $\theta \in [0, \underline{\theta})$ don't buy anything, $\theta \in [\underline{\theta}, \overline{\theta})$ only buy the platform and $\theta \in [\overline{\theta}, 1]$ buy platform and digital good. □

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