FLEXIBILITY AS AN INSTRUMENT
IN DIGITAL RIGHTS MANAGEMENT

By

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Flexibility as an Instrument in Digital Rights Management*

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Abstract

We consider the optimal design of flexible use in a digital-rights-management policy. The basic model considers a single distributor of digital goods and a continuum of consumers. Each consumer can acquire the digital good either as a licensed product or as an unlicensed copy. The availablity of (or access to) unlicensed copies is increasing both in the number of licensed copies and in the flexibility accorded to licensed copies. We thus analyze the optimal design of flexibility in the presence of unlicensed distribution channels (the "greynet").

We augment the basic model by introducing a "secure platform" that is required to use the digital good. We compare the optimal design of flexibility in the presence of a platform to the one without a platform. Finally, we analyze the equilibrium provision when platform and content are complementary goods but are distributed and priced by different sellers.

Keywords: Digital Rights Management, Platform, Flexibility, Piracy
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1 Introduction

1.1 Motivation

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 the 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 good. 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. DRM systems can thus be viewed as a response by content providers intended to increase users' valuation of the content without risking additional sales.

The current paper aims 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 will allow the seller to charge a higher price for a licensed copy. On the other hand, with an increase in the flexibility comes the risk that a non-paying customer will get, legally or not, access to the digital good. Hence an increase in flexibility may undermine sales volume. We explicitly model the choice of flexibility in an environment where perfect security is only possible in the limit when flexibility is severely restricted. This is meant to represent the pervasive view that the Internet will always be a "greynet" without perfect security provisions.[1]

We begin our analysis with a single content provider who offers a digital good to many consumers. The consumers are ex ante identical and have to choose between acquiring a licensed copy of the product and hoping to receive an unlicensed copy. The likelihood that the consumer will be able to receive an unlicensed copy is increasing both in the number of licensed copies and in their permitted flexibility. 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 will obtain access to an unlicensed copy. The resulting equilibrium policies of the content provider will attempt to find the optimal balance between flexibility and sales. In equilibrium, the ex ante identical agents will be split into buyers of licensed products

[1] We refer to "greynet" here to describe the use of digital files outside the strictly licensed context. This includes both the use of unlicensed copies on a small scale and the possibility of file sharing through peer-to-peer networks. Biddle, England, Peinado & Willman (2003) used the term "darknet" to describe exclusively peer-to-peer networks.

and consumers of unlicensed copies. The equilibrium volume of sales will be determined endogenously by price and flexibility. An important determinant of the equilibrium policies will be 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 then extend our analysis to heterogeneous buyers with either differential valuations for the digital product or differential access rates to licensed copies.

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. Under the iTunes DRM rules, each music file can be played on five devices at the same time that have to be authorized by the buyer of the file. Individual files can be burned on CDs without restriction, but every playlist, i.e. specific arrangement of several files, can only be burned seven times (see Inc (2005)). Apple's success in selling music files is closely connected to its introduction of the portable music player iPod. In addition to having a hard disk with 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.[2]

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 extend the model to include 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 make the assumption that, although the digital good may be acquired in the form of an unlicensed copy, it will still have to run on the platform sold by the content provider. 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 unlicensed appearance than the digital good itself. We then show that the content provider who sells a platform will find it optimal to provide each user with a higher and socially more efficient level of flexibility that the provider who doesn't sell a platform. Indeed the

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

arrival of the iPod and iTunes platform was accompanied by a much more flexible DRM system than the ones adopted earlier by the music industry itself.

The price of the digital good itself will be rather low, considering the high level of flexibility, and unlicensed copies will continue to circulate. However, the platform provider is less concerned about the unlicensed segment of the market, because he can recover part of the surplus that arises in the unlicensed segment 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 will leave 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. 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.

In reality, the digital good and the platform itself are often sold by different vendors. In the case of the audio files, for example, the digital goods are sold by the record companies, whereas the platform is provided by Apple in form of the iPod. The previous analysis of an integrated company thus suggests that there is a natural conflict between the owner of the digital good and the owner of 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 will want 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 will therefore want 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 therefore conclude with an analysis of the strategic interaction between content provider and platform provider in the presence of complementarities between their products. We show that the resulting equilibrium will lead to lower flexibility, a higher number of sold copies of the digital good, and a lower price for the platform. The conflict between content provider and platform provider predicted by our model has in fact emerged in recent discussions between Apple and the music industry. A recent article in the Financial Times, 2/28/05, quotes an industry insider as saying "Our music is not something to be given away to sell iPods." The concern is that the current price of the digital goods is too low and generates revenue for the owner of the platform but not for the owner of the digital goods.

An open issue for future research is the role of competing platforms in the context of DRM. Most other online music providers, e.g., Walmart, use Microsoft's Windows Media Audio (WMA) file format and combine it either with Microsoft's DRM-enabled player or one of their own. Exceptions are Sony's music store Connect (which has its own file format ATRAC, combined with its own DRM technology OpenMG) and RealNetworks' RealPlayer Music Store (which offers files in both Apple's format and Microsoft's).

1.2 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 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 & Lichtman (1999) emphasize that selling to groups may reduce demand uncertainty (just as bundling reduces it) and thus enable more profitable pricing. Parker & 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 & 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.

In an intertemporal setting, Takeyama (1997) finds that piracy among low-valuation consumers can reduce the provider's price-commitment problem if the good is durable over time. The negative effect of piracy on the quality the provider offers for his goods is studied in an early paper by Novos & Waldman (1984); they show that increased copyright protection raises the offered quality.

Regarding illegal online sharing of music, recent empirical studies by Oberholzer-Gee & Strumpf (2004) and Rob & 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 for a digital good is given by

$$v_i \ln(\lambda).$$

The valuation v_i represents the willingness to pay for the digital good, whereas $\lambda \in [1, \bar{\lambda}]$ represents the flexibility with which the digital good can be used by the consumer. In the most direct interpretation, λ is the number of copies the consumer is allowed to make.

We begin our analysis with the case of homogeneous buyers, or $v_i = v$ for all i. We later extend the analysis to heterogeneous consumers. In that case, we shall assume that $v_i = i$ and that the agents 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 it sells the digital goods 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, the revenue is equal to the net profit, 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

$$u(p,\lambda) = v_i \ln(\lambda) - p.$$

We refer to the digital good that is purchased from the seller as a *licensed product*. Alternatively, consumer i can attempt to receive an *unlicensed copy* of the digital good. We assume that unlicensed copies can only be made from licensed ones, but our results easily extend to the case where they can also be obtained from unlicensed ones. However, consumer i cannot be certain of receiving an unlicensed copy. Let the probability that he receives an unlicensed copy be given by

$$\alpha\lambda q \in [0,1].$$

The key idea is that the probability of receiving an unlicensed good is proportional to the number q of licenses sold and the flexibility λ with which they are sold.

[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.

The parameter α represents the exogenous access rate to digital goods and characterizes the permeability of the content-distribution environment, not the good itself. We consider α to be influenced by both technical and nontechnical factors, so increased permeability can result, e.g., from more lenient copyright law or less vigilant enforcement of existing copyright law, from more lenient or more easily circumventable DRM, or from factors as higher Internet bandwidth or contact frequency among consumers. For this reason, it will often be natural to think of consumers as being heterogeneous with respect to α; for example, college students might have very different access to a variety of sharing technologies from, say, senior citizens with an interest in classical music.

The utility of a copy of the digital good is given by

$$u_c(\lambda_c) = v_i \ln \lambda_c.$$

However, because consumer i cannot be certain of receiving an unlicensed copy, his expected utility with respect to unlicensed access is given by:

$$\alpha \lambda q (v_i \ln \lambda_c).$$

We choose this functional form for analytical convenience but plan to extend our results to more general specifications.

The level λ_c of flexibility of an unlicensed copy may or may not be equal to the flexibility of a licensed copy. In one scenario, a consumer receives a music file from a friend after the friend authorizes him as a listener. In this case, the consumer lacks the flexibility of authorizing additional devices, which he would have if he owned an original. In other scenarios, the loss in utility could be attributable to monetary costs of sharing or expected costs, such as the risk of fines for copyright infringement. In still other scenarios, an unlicensed copy of the digital good may have very few constraints attached to it and this may lead to $\lambda_c = \bar{\lambda}$.

Finally, in the second part of the paper, we shall 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 Equilibrium Pricing

In this section we analyze the provision of flexibility and the pricing policy by the content provider. In Subsection 3.1 we start with the case of ex ante identical consumers. In Subsection 3.2 we analyze the case of heterogeneous consumers and the element of differentiation will be the rate at which consumers have access to unlicensed copies of the digital good.

3.1 Homogeneous Consumers

The value of the digital good is identical for each consumer and $v_i = v$ for all i. In the presence of a "greynet,"a potential buyer can either acquire the digital good as a licensed product or obtain it as an unlicensed copy. The probability of obtaining an unlicensed copy is increasing in the number of licensed copies. With identical consumers, in equilibrium the net utility from the purchase of a licensed product and the expected utility from a unlicensed copy will have to be equalized. We denote by $q \in [0,1]$ the fraction of consumers who buy the digital good. In equilibrium, q is determined such that each consumer is indifferent between buying a licensed copy or trying to acquire an unlicensed copy. The indifference between buying and copying is characterized by:

$$v \ln \lambda - p = \alpha \lambda q \ln \lambda_c. \tag{1}$$

After we normalize the basic valuation to $v = 1$, the equilibrium indifference (1) allows us to compute the demand function for the digital good:

$$q(p, \lambda) = \frac{\ln \lambda - p}{\alpha \lambda \ln \lambda_c}. \tag{2}$$

The demand for the digital good is decreasing in p and initially increasing but eventually decreasing in λ. The demand $q(\cdot)$ as function of the flexibility λ is single-peaked. The trade-off for the seller is that, initially, an increase in flexibility leads to a higher value of the product and hence a higher demand. Yet, eventually, the marginal utility of any single consumer for flexibility is decreasing (though it remains positive), and hence it will increase the circulation of unsold copies and ultimately lead to lower demand.

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

$$\pi(p, \lambda) = p \frac{\ln \lambda - p}{\alpha \lambda \ln \lambda_c}. \tag{3}$$

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

Proposition 1 (Equilibrium Price and Flexibility)

1. *The equilibrium price p^* for the digital good is:*

$$p^* = \begin{cases} \ln \frac{1}{\alpha \ln \lambda_c} - 1, & \text{if} \quad \alpha < \frac{1}{e^2 \ln \lambda_c}; \\ 1, & \text{if} \quad \alpha \geq \frac{1}{e^2 \ln \lambda_c}. \end{cases}$$

2. *The equilibrium flexibility* λ^* *is:*

$$\lambda^* = \begin{cases} \frac{1}{\alpha \ln \lambda_c}, & \text{if} \quad \alpha < \frac{1}{e^2 \ln \lambda_c}; \\ e^2, & \text{if} \quad \alpha \geq \frac{1}{e^2 \ln \lambda_c}. \end{cases}$$

3. *The equilibrium sales volume* q^* *is:*

$$q^* = \begin{cases} 1, & \text{if} \quad \alpha < \frac{1}{e^2 \ln \lambda_c}; \\ \frac{1}{\alpha e^2 \ln \lambda_c}, & \text{if} \quad \alpha \geq \frac{1}{e^2 \ln \lambda_c}. \end{cases}$$

Proof. The first-order conditions for maximizing the profit function (3) are

$$\frac{\partial \pi (p, \lambda)}{\partial p} = \frac{\ln \lambda - 2p}{\alpha \lambda \ln \lambda_c} = 0 \tag{4}$$

and

$$\frac{\partial \pi (p, \lambda)}{\partial \lambda} = p \frac{1 - \ln \lambda + p}{\alpha \lambda^2 \ln \lambda_c} = 0. \tag{5}$$

Solving equation (4) for p and inserting it in equation (5), we obtain $p = 1$ and $\lambda = e^2$, resulting in the quantity $q = \frac{1}{\alpha e^2 \ln \lambda_c}$. Because the demand (2) is limited to $q \leq 1$, the maximization is constrained by $q(p, \lambda) = 1$ for $\alpha < \frac{1}{e^2 \ln \lambda_c}$. Solving this restriction for p and inserting it in equation (5), we obtain $p = -\ln(\alpha \ln \lambda_c) - 1$, $\lambda = \frac{1}{\alpha \ln \lambda_c}$, and $q = 1$ for $\alpha < \frac{1}{e^2 \ln \lambda_c}$. ■

In equilibrium, the outside option for every consumer, namely the expected utility $\alpha \lambda q \ln \lambda_c$ of sharing the good instead of buying it, is constant.[4]

For small values of α, the provider optimally sells to all consumers. The existence of a "greynet" only presents a small threat to the sales volume of the provider. The provider completely compensates for the threat of unlicensed copies by lowering his price. He also reduces the flexibility from the socially optimal level of flexibility to reduce the expected benefit from obtaining an unlicensed copy. The effect an increase in the permeability α has on the outside option will therefore be compensated for by reducing the allowed flexibility. Because changes in the flexibility also affect the utility of the consumers who buy the good, the provider also varies the price, along with the flexibility, in response to changes in permeability. For large α, this is obtained by setting price and flexibility constant, in such a way that the decrease in quantity exactly offsets every increase in permeability.

Looking at the provider's profit, we can state the next proposition.

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[4] The outside option $\alpha \lambda q \ln \lambda_c$ takes on the value $\alpha \frac{1}{\alpha \ln \lambda_c} 1 \ln \lambda_c = 1$, for $\alpha < \frac{1}{e^2 \ln \lambda_c}$, and $\alpha e^2 \frac{1}{\alpha e^2 \ln \lambda_c} \ln \lambda_c = 1$, for $\alpha \geq \frac{1}{e^2 \ln \lambda_c}$; so $\alpha \lambda q \ln \lambda_c = 1$ for all α.

Proposition 2 (Comparative Statics)
The equilibrium variables price p^*, flexibility λ^*, and sales q^* and the total revenue are decreasing in α.

Proof. Inserting the optimal values of p and λ in the profit function (3) yields profit

$$\pi(\alpha) = \begin{cases} -\ln(\alpha \ln \lambda_c) - 1 & \text{if} \quad \alpha < \frac{1}{e^2 \ln \lambda_c} \\ \frac{1}{\alpha e^2 \ln \lambda_c} & \text{if} \quad \alpha \geq \frac{1}{e^2 \ln \lambda_c} \end{cases}.$$

Then the first derivative is

$$\pi'(\alpha) = \begin{cases} -\frac{1}{\alpha \ln \lambda_c} & \text{if} \quad \alpha < \frac{1}{e^2 \ln \lambda_c} \\ -\frac{1}{\alpha^2 e^2 \ln \lambda_c} & \text{if} \quad \alpha \geq \frac{1}{e^2 \ln \lambda_c} \end{cases},$$

which is negative for all $\alpha > 0$. ■

3.2 Heterogeneous Consumers

Suppose now that consumers vary in their ability or propensity to obtain an unlicensed copy of the digital good instead of buying a licensed copy. Then we should expect consumers with high ability to rely on sharing and consumers with low ability to rely on buying. Let the individual ability to share be σ_i, uniformly distributed on the unit interval $[0, 1]$. This ability influences the probability of receiving an unlicensed copy, which is now given by

$$\sigma_i \alpha \lambda q.$$

With heterogeneous consumers, we are no longer working with a mixed-strategy equilibrium. Because consumers differ in their outside option, those who have a large ability to share will do so, while consumers with low ability will buy a licensed copy. The marginal consumer σ is defined by indifference between buying or trying to share:

$$u(p, \lambda) = \sigma \alpha \lambda q u_c(\lambda_c).$$

Again normalizing the basic valuation to $v = 1$, this indifference constraint now takes on the form

$$\ln \lambda - p = \sigma \alpha \lambda q \ln \lambda_c. \tag{6}$$

All consumers with ability $\sigma_i \leq \sigma$ will buy a licensed copy; so the total quantity q that is sold is equal to the marginal ability σ. The demand function can then be derived from the indifference constraint (6), using $\sigma = q$, as

$$q(p, \lambda) = \sqrt{\frac{\ln \lambda - p}{\alpha \lambda \ln \lambda_c}}.$$

Using this demand function, the provider's profit, as a function of price and flexibility, is

$$\pi(p,\lambda) = p\sqrt{\frac{\ln\lambda - p}{\alpha\lambda\ln\lambda_c}}. \tag{7}$$

Profit maximization now leads to the following result.

Proposition 3 (Heterogeneity)

1. *The equilibrium price p^* for the digital good is:*

$$p^* = \begin{cases} \ln\frac{1}{\alpha\ln\lambda_c} - 1, & \textit{if} \quad \alpha < \frac{1}{e^3\ln\lambda_c}; \\ 2, & \textit{if} \quad \alpha \geq \frac{1}{e^3\ln\lambda_c}. \end{cases}$$

2. *The equilibrium flexibility λ^* is:*

$$\lambda^* = \begin{cases} \frac{1}{\alpha\ln\lambda_c}, & \textit{if} \quad \alpha < \frac{1}{e^3\ln\lambda_c}; \\ e^3, & \textit{if} \quad \alpha \geq \frac{1}{e^3\ln\lambda_c}. \end{cases} .$$

3. *The equilibrium sales volume q^* is:*

$$q^* = \begin{cases} 1, & \textit{if} \quad \alpha < \frac{1}{e^3\ln\lambda_c}; \\ \sqrt{\frac{1}{\alpha e^3\ln\lambda_c}}, & \textit{if} \quad \alpha \geq \frac{1}{e^3\ln\lambda_c}. \end{cases} .$$

Proof. The first-order conditions for maximizing the profit function (7) are

$$\frac{\partial\pi(p,\lambda)}{\partial p} = \frac{2\ln\lambda - 3p}{2\sqrt{\lambda\alpha\ln\lambda_c(\ln\lambda - p)}} = 0 \tag{8}$$

and

$$\frac{\partial\pi(p,\lambda)}{\partial\lambda} = \frac{p(p+1-\ln\lambda)}{2\lambda\sqrt{\alpha\lambda\ln\lambda_c(\ln\lambda - p)}} = 0. \tag{9}$$

Solving equation (8) for p and inserting it in equation (9), we obtain $p = 2$ and $\lambda = e^3$, resulting in the quantity $q = \sqrt{\frac{1}{\alpha e^3\ln\lambda_c}}$. As above, demand is limited to $q \leq 1$ for small α. Solving the restriction $q(p,\lambda) = 1$ for p and inserting it in equation (9), the restricted values are obtained as $p = -\ln(\alpha\ln\lambda_c) - 1$, $\lambda = \frac{1}{\alpha\ln\lambda_c}$, and $q = 1$, for $\alpha < \frac{1}{e^3\ln\lambda_c}$. ■

With heterogenous consumers, the seller is actively sorting the consumers into two market segments. The user with a low ability to access unlicensed copies will buy the product from the seller. As the probability of having access to unlicensed copies increases, consumers will eventually find it too expensive to buy the product and will attempt to obtain an unlicensed copy. For small values of α, it will still be the case that all consumers buy a licensed copy (i.e., for $\alpha < \frac{1}{e^3\ln\lambda_c}$), and the seller will simply reduce price and flexibility to entice the marginal buyer to purchase the licensed product.

On the other hand, for higher levels of permeability α, some consumers will stop buying, and the separation into buyers and sharers will arise in equilibrium. The equilibrium will now be defined through the marginal consumer characterized by the marginal σ_i. The provider's choices of price and flexibility now ensure that the outside option of the marginal consumer is constant for all α. Because the quantity varies with the permeability α, the marginal consumer also changes.

The second new aspect is that the provider now offers higher flexibility and charges a higher price for it. This becomes possible, because heterogeneity means that only the consumers with low sharing ability, who have a low outside option, buy licensed copies. Therefore, the provider's trade-off between flexibility and price is loosened, resulting in a higher level of flexibility at a higher price.

A third aspect of consumer heterogeneity is that the critical α is larger than with homogeneous consumers. This implies that the permeability can be higher than it is in the case of homogeneous consumers and that the provider can still sell to everybody.

4 Sales of Platforms for Digital Goods

In the presence of the "greynet,"the provider will not be able to capture the entire 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 to leave this outside option as a 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 or Sony's NetMD.

In economic terms, the platform constitutes a complimentary product to the digital good. In Subsection 4.1, we first 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 Subsection 4.2, we consider the more realistic situation in which ownership of the platform and ownership of the digital good are separate, as is the case in the digital music industry. In this case, a classic conflict arises between the platform provider and the content provider; this result sheds light on the recent positioning in the music industry.

4.1 Integrated Firm

In the case of an integrated firm, the platform and the digital good are sold by the same firm. 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 the residual surplus that the buyers obtained in the market for digital goods. Recall that, with homogenous buyers and in equilibrium, every consumer received the same net utility $\alpha\lambda q \ln \lambda_c$, whether he bought or shared the digital good.

We denote by r the price of the platform. With the platform, the seller will attempt to recover through r the residual surplus or rent that the consumers retained in section 3 because of the greynet. In fact, the price of the platform will exactly reflect the consumers' willingness to pay for the platform; so the provider will set the platform price at

$$r = \alpha\lambda q \ln \lambda_c.$$

Suppose that the platform is sold at the same time as the digital good; so consumers who try to obtain unlicensed copies don't know yet whether they will be successful. Then all consumers will buy the platform at price r, which equals their expected utility.

The choice between buying an unlicensed copy and trying to share is not changed by the existence of the platform, and it is determined by the indifference constraint as above:

$$\ln \lambda - p = \alpha\lambda q \ln \lambda_c.$$

The question is how the provider will now set the flexibility and price of the digital good in order to maximize his profit from sales of it and the platform.

Proposition 4 (Integrated Firm)

1. *The equilibrium price of the platform is* $r^* = \alpha\bar{\lambda} \ln \lambda_c$.
2. *The equilibrium price of the digital good is* $p^* = \ln \bar{\lambda} - \alpha\bar{\lambda} \ln \lambda_c$.
3. *The equilibrium flexibility is* $\lambda^* = \bar{\lambda}$.

Proof. Suppose the integrated firm sets the above prices and flexibility. At the price p^* every consumers are indifferent between buying the digital good and trying to share, given that all other consumers buy the good ($q = 1$). So the combination of $p = p^*$ and $q = 1$ is an equilibrium in the digital-good market. This equilibrium leaves a rent of $\alpha\bar{\lambda}\ln\lambda_c$ to every consumer through the outside option provided buy the possibility of sharing. Since this rent is the consumers' maximal willingness to pay for the platform, the provider's profits are maximized by setting the platform price equal to r^*.

Given these prices and flexibility $\lambda = \bar{\lambda}$, the total profit of the integrated firm is

$$pq + r = \left(\ln\bar{\lambda} - \alpha\bar{\lambda}\ln\lambda_c\right) 1 + \alpha\bar{\lambda}\ln\lambda_c = \ln\bar{\lambda},$$

which is the maximum social surplus. ■

The price that the consumers are willing to pay for the platform equals the utility they derive from being able to use the digital good. The provider therefore maximizes the utility from the digital good by allowing full flexibility and ensures that every consumer wants to buy the digital good by setting a very low price. The provider then captures the entire consumer surplus by selling the necessary platform and charging for it the total utility the consumers will derive from the digital good.

From a social welfare point of view, the provision of digital good and platform by a single firm leads to the socially efficient level of flexibility, i.e., maximum flexibility.

4.2 Separate Firms

Alternatively, the platform may be sold by a different firm from the one that sells the digital good. Then the provider of the digital good will not take into account the effect of his flexibility and price on the profit of the platform provider. This will lower the level of flexibility offered in equilibrium, but it is the equilibrium strategy for the content provider, because his revenue is determined by the sale of the content rather than the platform. The timing of the pricing game is as follows. The platform provider offers a price for the platform, the consumer makes his purchase decision regarding the platform, then the content provider offers the digital files and finally the consumer makes his purchase decision regarding the content. We now analyze the subgame perfect equilibrium of the dynamic game.

Proposition 5 (Separate Firms)

1. *The content provider sets an equilibrium price p^*:*

$$p^* = \begin{cases} \ln\frac{1}{\alpha\ln\lambda_c} - 1, & \text{if} \quad \alpha < \frac{1}{e^2\ln\lambda_c} \\ 1, & \text{if} \quad \alpha \geq \frac{1}{e^2\ln\lambda_c} \end{cases}$$

and a flexibility λ^*:

$$\lambda^* = \begin{cases} \frac{1}{\alpha\ln\lambda_c}, & \text{if} \quad \alpha < \frac{1}{e^2\ln\lambda_c} \\ e^2, & \text{if} \quad \alpha \geq \frac{1}{e^2\ln\lambda_c} \end{cases}.$$

2. *The equilibrium sales volume q^* of licensed copies sold is*

$$q^* = \begin{cases} 1, & \text{if} \quad \alpha < \frac{1}{e^2 \ln \lambda_c} \\ \frac{1}{\alpha e^2 \ln \lambda_c}, & \text{if} \quad \alpha \geq \frac{1}{e^2 \ln \lambda_c} \end{cases} .$$

3. *The platform provider offers an equilibrium price $r^* = 1$ and sells the platform to all consumers.*

Proof. As seen above, all consumers are left with the same rent $\alpha\lambda q \ln \lambda_c$, which represents their willingness to pay for the platform. Therefore, the platform provider maximizes his profit by charging the price $r = \alpha\lambda q \ln \lambda_c$ and selling the platform to all consumers.

Because all consumers buy the platform, the demand facing the digital-good provider is the same as in the case without a platform. Thus, the behavior of the digital-good provider is given by proposition 2.

The outside option is then $\alpha\lambda q \ln \lambda_c = 1$, which determines the platform price r^*. ■

The digital-good provider restricts flexibility to below the socially optimal level $\bar{\lambda}$. This is caused by the conflict of interest between the two providers. 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.

5 Conclusion

In this paper, we provided an elementary analysis of the role flexibility and platform play in DRM. The basic model showed 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 showed 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 (as is the case for music files), then a conflict over the optimal flexibility rule emerges again.

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.

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