Does Peer-to-Peer harm Copyright Owners? 
Protecting and Distributing Digital Products*

Anne Duchêne† and Patrick Waelbroeck‡
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Abstract
Peer-to-Peer technologies are often seen as a threat by copyright owners, as they encourage piracy by making digital copies easier. In response, music companies have implemented technical protection on originals, and asked for a strengthening of legal protection. But, P2P also represents a new means of distribution that involves almost no fixed costs of distribution and advertising for artists, as consumers not the firm bear the costs of searching, downloading and testing digital copies of original products before they make their purchase decision. We determine copyright owners’ protection and distribution strategies according to the level of legal protection, and we study its effect on profits and consumers’ surplus.

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†CERAS-ENPC, 28 rue des Saints Pères, 75007 Paris, France.
‡ECARES and FNRS, ULB, 50 av. Roosevelt, CP 114, 1050 Bruxelles, Belgium.
1 Introduction

To curb the dramatic growth of digital copies over the last years, major distribution companies have launched legal actions aimed at shutting down internet distribution sites and file-sharing technologies. None of those sites has come under more scrutiny than Napster, an online operator, which allowed registered users to exchange indexed music files in a compressed format (called MP3) freely and anonymously. Following a lawsuit filed by the Record Industry Association of America, Napster was found guilty of copyright infringement and was eventually shut down.\footnote{According to the ruling, Napster’s free exchange system did not comply with the “fair use” principle at the core of the copyright law: any cultural good can be duplicated as long as the owner of the copy keeps it for his own use. The case was far from marginal. At its peak, Napster attracted about 60 millions users who exchanged 40 millions digital music files. See the New York Times, February 18, 2002}

In the aftermath, Peer-to-Peer (P2P) Services and other file-sharing technologies took over, attracting a growing number of users. Contrary to Napster, P2P technologies allow users to download files directly from nearby computers. Unlike traditional means of copying, file-sharing technologies provide a large scale diffusion channel that is virtually impossible to monitor, as a single copy can be downloaded by any user across the world.

So far, public policies have addressed the issue by strengthening existing copyright laws, as illustrated by the 1998 U.S. Digital Millenium Copyright Act, prohibiting any means of circumventing technical measure of copyright protection. However, the economic implications of such legal arrangements have not yet been studied.

In this article, we propose a stylized model of the music industry to analyze the effect of an increase in copyright protection on consumers’ surplus and on the distribution and protection strategies of a firm facing online piracy. We focus our analysis on several important points that have been at the center of the Napster case.

First, we consider two means of intellectual property protection: legal
protection determined by governmental authorities, and technical protection implemented by copyright owners. Copyright owners can implement technical protection on their original products in order to prevent their duplication (as MP3 files). Technical protection has already been implemented by distributors of digital products under the name "Digital Rights Management" (DRM) or "Automated Rights Management" that can control the number of times a digital product is accessed as well as the number of copies that can be made.\(^2\) However, it is hard to argue to technical protection alone can completely eliminate online copying since it is always possible to crack software/hardware protection and diffusion of these anti-protection devices would be fast in P2P networks. Therefore, enforcement of the copyright law is also required. Legal protection consists in legal proceedings against copiers who must internalize the risk of being caught and the resulting penalty.

Secondly, we consider two different distribution technologies: a traditional distribution technology with advertisement (financed by record companies), and an online distribution technology (with the possibility to distribute music as MP3 files). On the one hand, the traditional technology involves large fixed costs of marketing, advertising, promotion and inventory control. As a result, only a handful of artists (with a large potential audience) are profitable to market. On the other hand, after the Napster experience, it has become clear that there is a cheaper way for some consumers to obtain information about new products, by searching, downloading and testing digital files available using file-sharing technologies. Thus, P2P technologies make it possible for some artists to enter the market at a low distribution cost, as consumers, not the firm, bear the cost of acquiring information. In summary, we view

\(^2\)Several tools to protect digital products are already in use: password protection (Online journal), software DRM protection (Adobe E-book, Windows and Real Media, hardware encryption protection (cable and satellite TV), hardware DRM protection (Content Scramble System for DVDs, discontinued Secure Digital Music Initiative project for mp3 files) and legally mandated software/hardware protected access and copies (Serial Copy Management System for Digital Audio Tapes). See Sobel (2003) for a discussion of business models that use DRM.
the traditional distribution as an information-push technology and P2P as an information-pull technology. Peitz and Waelbroeck (2003a) show how a multi-product firm can combine both marketing tools to increase profits.

Thirdly, we consider that a digital copy provides less value than an original, but at a cost that depends on the users' distutility of using computers and the internet to burn downloaded files. Indeed, less than half of the North American population uses the internet at home on a regular basis and less than 15 percent has a broadband connection. Moreover, consumers have preferences over the way they obtain music information. Some consumers prefer to use the internet; others prefer to listen to the radio or to samples in record stores or read reviews in specialized magazines. Moreover, with the implementation of technical protection and the reinforcement of copyright laws, protection-free digital copies can become more difficult and riskier to obtain. Finally, some users view digital copies as poor substitutes to original CDs, mainly because they greatly value lyrics, pictures and other information such as song and album title.

Despite the technological breakthrough of file-sharing technologies, the debate on the welfare implications of unauthorized copies goes a long way back in the economics literature. Liebowitz (1985) shows how publishers can indirectly appropriate revenues from users who photocopy copyrighted material. Publishers consider the value of unauthorized copies when they market authorized copies (charging a higher price for those originals that would be used to make copies). Besen and Kirby (1989) and Bakos et al. (1999) have extended this argument to small-scale copying/sharing and the analysis is similar to the pricing of a club membership. In a model where all consumers have the same valuations for the product and either purchase or copy it, Novos and Waldman (1984) show how an increase in copyright

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3See the Pew Internet Report by Horrigan and Rainie (2002).

4This information is most of the time available on the internet but is also time consuming to acquire. Moreover, from a technical point of view, the expected quality of a digital copy is inferior to the quality of an original product because of the compression algorithm and the probability to download a badly encoded or corrupted digital file.
protection can have positive effects on welfare, by saving the wasteful copying costs. In some cases, positive network externalities due to copies can benefit copyright owners as shown by Conner and Rumelt (1991), Takeyama (1994) and Shy and Thisse (1999). Finally, Takeyama (2002) shows how copies that provide information on the characteristics of a durable good can solve adverse selection problems in a two period model. Peitz and Waelbroeck (2003b) provide a review of the arguments found in the economics literature on the piracy of digital products. Recent empirical studies try to assess the effect of unauthorized copies on the market for the original product. For instance, Hui and al. (2001) study the impact of offline piracy on the legal demand for recorded music. They show that piracy decreases demand for originals, despite the positive effects such as demand-side externalities, sampling, sharing, etc. Peitz and Waelbroeck (2003c) analyze the impact of online piracy on CD sales using international data for 2000-2001 and hint that about 30 percent of the decline in sales in the U.S. during that period could be attributed to unauthorized music downloads.

Our model contributes to the literature on copyright protection and the welfare implications of illegal copies on two points. First, we model digital copies as means of information transmission about the characteristics of products distributed on P2P services. Thus, we do not need to rely on network externalities or indirect appropriation to highlight the potential benefits of unauthorized copies. Secondly, we endogenously determine the level of technical protection chosen by artists, and we emphasize its connection with legal protection. We find that increasing copyright protection raises the level of technical protection, as well as the profits, of firms marketing their products using the traditional distribution, while it is detrimental to online distribution. Moreover, a strengthening of legal actions against copiers leads to a reduction of consumers’ surplus due to the direct negative effect on copiers and the indirect negative effect on buyers of original products through the increase in technological protection and prices.

The remaining of the article is organized as follows. In section 2, we
describe the basic framework. In section 3, we analyze the effect of increasing legal protection on consumers and firms distribution their products online or traditionally. Section 4 discusses the main implications of P2P technologies. Section 5 draws the conclusions from our results.

2 The Model

We analyze the role of an increase in copyright protection on two different and extreme forms of distribution technologies that differ on how consumers acquire information.

*Distribution technologies.* On the one hand, the traditional technology allows artists to sell original versions of their records (with their full set of features: CD box, lyrics, pictures ...) at a large fixed cost of marketing and advertising noted $K$, which, for simplicity, we assume to give information about the products’ existence and characteristics to all consumers. On the other hand, the virtual Peer-to-peer technology allows consumers to search and test digital copies that we assimilate to downgraded versions of originals (with a limited set of songs or features). Thus the P2P technology allows artists to freely distribute their products online but only to informed consumers, i.e. to those who have downloaded digital copies. In other words, only consumers with a low opportunity cost of spending time online searching, downloading and testing digital files can become potential buyers. The marginal cost of production and distribution of the original is set to zero.

*Technical and legal protection.* Regardless of the distribution technology, there is online piracy, the amount of which depends on the extent of technical protection and legal enforcement of copyright protection. The artist can spend resources on technical protection of originals in order to make unprotected digital copies of his product more difficult to create and to find online. Technical protection $\alpha > 0$ can be implemented by the artist at an increasing and convex cost function $c(\alpha) > 0$. In addition to technical protection, original products can be legally protected. This protection is represented by the
extent of legal enforcement $\phi \geq 0$ that can be the consequence of laws such as the Digital Millenium Copyright Act. Thus $\phi$ represents the additional disutility of copying and corresponds to the increase in the expected cost of being caught using illegal copies.

*Music experience.* Consumers incur an opportunity cost $s$ of spending time searching and downloading digital music files using the P2P technology. We assume that $s$ is uniformly distributed on the segment $[0, \bar{s}]$ of mass 1. When listening to music (through promotions or through copying), consumers can either enjoy it or not. These states of nature occur with probability $\rho$ (good experience) and $1 - \rho$ (bad experience) respectively (with $0 \leq \rho \leq 1$). Copiers who like what they have listened to obtain a utility represented by the decreasing function $v_c(\alpha)$. Similarly, buyers of the original product obtain a utility $v_b(\alpha) > v_c(\alpha)$. We do not make explicit assumptions on the value of the original but rather on the differential between copies and originals, noted $\gamma(\alpha) = v_b(\alpha) - v_c(\alpha) > 0$. This function corresponds to the value of the original over the copy, such as additional songs, lyrics, booklet, pictures, song information, and so on. We assume that $\gamma(\alpha)$ is increasing and concave in $\alpha$, so that increasing technical protection hurts copiers more (through the reduction in the probability to obtain a protection-free copy) than buyers of the original (through a reduction in the fair use) and that the marginal effect of increasing $\alpha$ is decreasing with the level of $\alpha$.

In section 3.2, we will also assume that $v_c$ is not too convex (see the Appendix for the formal requirement).

Consumers who do not like the music get 0 utility, regardless of whether they learned the existence and the characteristics of the music through advertising or through a digital copy.

With the legal enforcement of copyrighted protection, the total expected cost of copying is $s + \phi$. It is worth noting that this cost could have taken

\footnote{All existing protection tools (password protection, encryption, software/hardware DRM) can be argued to satisfy these conditions. Moreover, our assumptions encompasses models in which technical protection leaves the value of the original unchanged while only decreasing the value of the copy, as illustrated in Section 3.3.}
the form of $s(1 + \phi)$ (as in Novos and Waldman (1984)). However, we do not consider that copiers with a higher downloading cost $s$ should suffer more from legal protection than others. Thus, we assume that legal protection creates an additional burden that is identical for all copiers.

Consumers’ expected utility is defined by $u(x, y)$, where $x \in \{0, 1\}$ corresponds to the decision to purchase the original ($x = 1$) or not ($x = 0$), and $y \in \{0, 1\}$ corresponds to the decision to download the digital copy ($y = 1$) or not ($y = 0$). We assume that $u(0, 0) = 0$.

3 Legal and technical protection

3.1 The artist distributes on the traditional technology

In this section, the artist uses the traditional distribution technology with the fixed marketing and advertising cost $K$.\footnote{We do not make a distinction between the artist and his label. Thus, we merge the fixed cost of distribution with the fixed cost of marketing and advertising. An artist then has to bear the whole cost in order to distribute his product traditionally.} We assume that advertisement reaches all consumers who are thus aware of the existence and the characteristics of the product. Hence, consumers take their purchasing decisions in a perfect information environment. Consumers who like the music (in proportion $\rho$) can purchase the original or copy the downgraded version.

The utility of purchasing the original version is $u(1, 0) = v_b(\alpha) - p$, and the utility of downloading a digital copy is $u(0, 1) = v_c(\alpha) - s - \phi$. Consumers purchase the original if

\[
\begin{align*}
\begin{cases}
u(1, 0) \geq u(0, 0) \iff p \leq v_b(\alpha) \\
u(1, 0) \geq u(0, 1) \iff s \geq p - \phi - \gamma(\alpha) = \delta
\end{cases}
\end{align*}
\]

If the first inequality holds, consumers who like the product (in proportion $\rho$) purchase it if their opportunity cost of using the P2P technology is such that $s \geq \delta$. The artist faces the following demand:
\[ d(p) = \begin{cases} 
\rho & \text{if } p \leq \gamma(\alpha) + \phi \\
\rho \frac{\gamma - \phi}{\alpha} & \text{if } \gamma(\alpha) + \phi \leq p \leq \min\{v_b, \bar{\alpha} + \phi + \gamma(\alpha)\} \\
0 & \text{otherwise} \end{cases} \]

The artist maximizes his profit function with respect to \( \alpha \) and \( p \). His objective function is

\[
\max_{\alpha,p} \pi = \frac{\rho \theta}{\alpha} (\bar{\alpha} - p + \gamma(\alpha) + \phi) - c(\alpha) - K \\
\text{s.t. } \gamma(\alpha) + \phi \leq p \leq \min\{v_b, s + \phi + \gamma(\alpha)\}.
\]

This leads to the following interior solution: the artist sets a technical protection \( \alpha^* \) such that \( \rho \gamma'(\alpha^*) \frac{\gamma + \gamma(\alpha^*) + \phi}{2s} - c'(\alpha^*) = 0 \), and a price \( p^* = \frac{\gamma + \gamma(\alpha^*) + \phi}{2\rho} \). The corner solution gives \( p^* = \phi + \gamma(\alpha) \) and \( \alpha^* \) such that \( \rho \gamma'(\alpha^*) - c'(\alpha^*) = 0 \).

In the following proposition, we analyze how technical protection, \( \alpha \), changes with respect to an increase in legal protection, \( \phi \).

**Proposition 1**

The degree of technical protection \( \alpha^* \) is an increasing function of legal protection \( \phi \).

**Proof 1**

Let \( F(\alpha, \phi) = \rho \gamma'(\alpha) \frac{\gamma + \gamma(\alpha) + \phi}{2s} - c'(\alpha) \). First consider an interior solution. Applying the implicit functions theorem to \( F(\alpha, \phi) = 0 \), we get \( \frac{\partial \alpha}{\partial \phi} = -\frac{\gamma'(\alpha)/2s}{\partial \pi/\partial \alpha} \).

Since \( \gamma' \geq 0 \) and the denominator is negative by the concavity of the profit function (guaranteed by the assumption \( \gamma'' < 0 \)), we have \( \frac{\partial \alpha}{\partial \phi} \geq 0 \). For the corner solution, the effect of \( \phi \) on \( \alpha \) is zero.

In Proposition 2, we analyze how the price and the demand for the original change in response to an increase in \( \phi \).

**Proposition 2**

The demand for originals and the optimal price are increasing functions of copyright protection.
**Proof 2**

We have \( \hat{s} = p - \phi - \gamma(\alpha) = \frac{s - \phi - \gamma(\alpha)}{2} \). Thus, \( \frac{d\hat{s}}{d\phi} = -\frac{1}{2}(1 + \gamma'(\alpha)\frac{d\alpha}{d\phi}) \). Since \( \gamma'(\alpha) \geq 0 \) by assumption and \( \frac{d\alpha}{d\phi} \geq 0 \) by Proposition 1, we obtain \( \frac{d\hat{s}}{d\phi} \leq 0 \), which implies that the demand (which is equal to \( \frac{p^*}{s}(\hat{s} - \hat{s}) \)) increases with \( \phi \). The optimal price is given by \( p^* = \frac{s + \phi + \gamma(\alpha)}{2} \). Thus, \( \frac{dp^*}{d\phi} = \frac{1}{2}(1 + \gamma'(\alpha)\frac{d\alpha}{d\phi}) \), which implies that \( \frac{dp^*}{d\phi} \geq 0 \) using a similar reasoning.

Propositions 1 states that a reinforcement of legal protection (as a consequence of the Digital Millenium Copyright Act for instance) makes artists increase technical protection. Moreover, Proposition 2 implies that increasing technical protection in turn increases the size of the demand for originals, as it increases the quality differential between originals and copies \( \gamma(\alpha) \). This leads to a higher willingness to pay and to a higher price. These two effects increase profits as stated in Proposition 3.

**Proposition 3**

The optimal profit \( \pi^* \) is an increasing function of legal protection \( \phi \).

**Proof 3**

Applying the envelope theorem shows that \( \frac{d\pi^*}{d\phi} = \frac{p^*}{2s}(\hat{s} + \phi + \gamma(\alpha)) \geq 0 \).

Thus, artists who distribute traditionally benefit from a stronger legal protection since it increases the size of the potential demand. However, such technical protection comes at a cost: the reduction in consumers’ surplus.

**Proposition 4**

Increasing legal protection decreases consumers’ surplus.

**Proof 4** See the Appendix.

The intuition is the following. Consumers who still copy after the increase in copyright protection strictly lose, because of the direct negative effect of \( \phi \) on their surplus. Similarly, consumers who still purchase the original strictly lose, since \( v'_q(\alpha) \leq 0 \), and more importantly \( \frac{d\pi}{d\phi} \geq 0 \) by Proposition 2. Finally,
we show in the Appendix that consumers who switch from the copy to the original also have a lower surplus because of the higher price. This proposition contrasts with the result obtained by Novos and Waldman (1984) on two points. First, increasing copyright protection has both a direct negative effect on copiers, but also an indirect negative effect on buyers, through the increase in technical protection and the higher price. Secondly, the market is not “covered” by the copy. Hence, after the increase in legal protection, some consumers do not copy anymore, reducing consumers’ surplus further.

3.2 The artist chooses the P2P technology

In this section, the artist distributes his product using a file-sharing technology. We assume that consumers are not initially informed about the characteristics of the product, but they can acquire information by downloading digital copies. Consumers who have copied the product and have had a good music experience have the possibility to directly purchase the original from the artist. The expected utility of downloading the digital copy is $u(0, 1) = \rho v_c(\alpha) - s - \phi$ (the probability to like the music being $\rho$).

The consumer who is indifferent between downloading a copy or not is such that $\bar{s} = \rho v_c(\alpha) - \phi$. Hence, only consumers with a low search cost and who like the music can become potential buyers. On the one hand, copiers who did not like the music do not purchase the original version, as their utility of purchasing the original product would be $-p - s - \phi < 0$. On the other hand, consumers who have copied the product (of mass $\frac{\rho v_c(\alpha) - \phi}{\bar{s}}$) and who liked it (in proportion $\rho$) have an expected utility $u(1, 1) = \rho (v_b(\alpha) - p) - s - \phi$. It is clear that copiers who like the music will purchase the

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7The process of purchasing the original requires the availability of a connection to an internet site or a file-sharing software, which then proposes a connection to a merchant site. We thus assume that consumers can not buy at random products for which the fixed costs of marketing and promotion $K$ has not been spent. In other words, products which have not been distributed traditionally are not available in brick-and-mortar stores and can only be discovered through a time consuming online search process.

8It is worth noting that in this section a consumer might have both versions (copy and
original provided that $p \leq \gamma(\alpha)$. Indeed, copiers who like what they listened to have an extra utility $\gamma(\alpha) - p$ of purchasing the original instead of just copying.

The artist faces the following demand:

$$d(p) = \begin{cases} 0 & \text{if } p > \gamma \\ \frac{\rho_0 p(\rho \psi v_c(\alpha) - \phi)}{\bar{s}} & \text{if } p \leq \gamma \end{cases}$$

This leads to the following optimization program:

$$\begin{align*}
\max_{\alpha, \phi} & \quad \pi = \frac{\rho_0 p(\rho \psi v_c(\alpha) - \phi)}{\bar{s}} - c(\alpha) \\
\text{s.t.} & \quad p \leq \gamma(\alpha) \text{ and } \phi \leq \rho v_c(\alpha).
\end{align*}$$

At the optimum, the effect of increasing $\alpha$ on profits is given Lemma 1.

**Lemma 1**

$$F(\alpha, \phi) = \frac{\partial \Pi^*}{\partial \alpha} = \frac{1}{\bar{s}}[\rho \psi' (\alpha)(\rho \psi v_c(\alpha) - \phi)] + \frac{1}{2} \rho^2 \psi' (\alpha) v_c' (\alpha) - c' (\alpha)].$$

Technical protection has two opposing effects on revenue generated by online sales. The first expression in between brackets is positive and gives the marginal revenue due to increasing technical protection resulting into a higher willingness to pay for the original. Given our assumptions $v_c'(\alpha) < 0$ and $c'(\alpha) > 0$, the second expression of $F(\alpha, \phi)$ is negative and represents the total marginal cost of increasing technical protection: a direct effect $c'$ and an indirect effect resulting from the loss of revenue due to a smaller segment of potential buyers. Thus, when $F(\alpha, \phi) < 0$, the negative effect dominates and the firm chooses not to implement technical protection: $\alpha^* = 0$. A sufficient condition for minimal technical protection can be obtained by rearranging terms and partially substituting $\gamma = v_b - v_c$ in Lemma 1:

$$F(\alpha, \phi) = (v_b - 2v_c)v_c' \frac{\psi^2}{\bar{s}} - c'' - \frac{\psi_0}{\bar{s}} \phi \gamma' + \frac{\psi^2}{\bar{s}} v_b' v_c.$$  

The last three terms are negative [original] of the same product, contrary to the last section. This is due to the fact that the informational structures are different. Since consumers are initially uninformed about the product, they first have to test the product before knowing whether they like it or not. Thus their actions are sequential.
and the first is also negative provided that $v_b > 2v_c$. Thus, when the quality differential between the original and the copy is large, the firm chooses not to implement technical protection on products that are distributed online. When this is not the case, Proposition 5 describes how technical protection changes with an increase in copyright protection.

**Proposition 5**

*The level of technical protection $\alpha$ is a decreasing function of copyright protection $\phi$.***

**Proof 5**

*See Appendix.*

The intuition of Proposition 5 is straightforward. Increasing copyright protection reduces the potential demand for original products distributed online, as potential buyers need to download a digital copy first. In order to compensate this loss, it is optimal to reduce the level of technical protection. We now analyze the effect of copyright protection on the profits of the firm.

**Proposition 6**

*An increase in copyright protection decreases the profits of firms distributing their products using P2P.*

**Proof 6**

*Applying the envelope theorem shows that $\frac{\partial \Pi^*}{\partial \phi} = -\frac{\varphi(\alpha)}{\dot{\phi}} < 0$.***

Proposition 6 is easy to understand: an increase in legal protection reduces the demand for copies and thus the potential demand for originals, while price and technical protection are both reduced, having opposite effects on profits.

Finally, the following proposition analyze how consumers are affected by a strengthening of the copyright law. Since the firm extracts all surplus from buyers, consumers only obtain the surplus from the copy. But, some consumers waste resources on copying without enjoying the product.
Proposition 7

Increasing copyright protection has two opposing effects on consumer surplus: (i) it decreases the social loss due to copying, and (ii) it decreases buyers’ surplus.

Proof 7

See the Appendix

The main difference with the previous distribution technology is that there is always both a benefit and a cost of copyright protection on consumers surplus. The reason is that increasing $\phi$ reduces the number of copiers and thus both the number of copiers who waste resources on downloading music they do not like and the number of copiers who become buyers of the original product.

3.3 Application: effect of an increase in copyright protection on the profits of the industry in a parametric example

Suppose that consumers’ utilities are specified as follows: $v_b = r$ and $v_c = (1-\alpha)r$ ($0 \leq \alpha \leq 1$). With this specification $\gamma(\alpha) = \alpha r$, and the assumptions $v_c'(\alpha) < 0$ and $\gamma'(\alpha) > 0$ are satisfied. Moreover, $v_c'' = 0$ and the convexity requirement is automatically satisfied. This parametric example corresponds to the specification used by Besen and Kirby (1989).

When the artist distributes his product traditionally, he sets a price $p^* = \frac{c\phi + \frac{\gamma(\alpha)}{2}}{2\phi} - \frac{r\phi}{2\phi - r^2\rho}$, and a technical protection $\alpha^* = \frac{r\phi}{2\phi - r^2\rho} \geq 0$ (the denominator is positive by the second order condition). This yields a profit using the traditional distribution technology of $\pi^*_1 = \frac{\phi^2}{4\phi - 2r\rho}$.

When the artist uses the P2P technology, he sets a price $p^* = \alpha^* r$ and a level of technological protection $\alpha^* = \frac{r\phi(r-\phi)}{\phi^2 + 2r^2\rho^2}$. It is easy to check that the optimal profits is $\pi^*_2 = \frac{r^2\rho^2}{2\phi(\phi^2 + 2r^2\rho^2)}$.

In the following two figures, we compare the profits of the two distribution technologies for two different values of copyright protection $\phi$. The flattest
curve corresponds to the profit obtained by using the P2P technology, and the other curve to the profits of a firm using the traditional distribution technology. The trade-off between the distribution technologies lies on the potential market size of the firm.

The other parameters are set to $\bar{s} = 1, r = 1, K = .45, c = 1$. We could not find any permissible configurations of the parameters that yielded other qualitative results. For any given values of $\phi$, firms with a low market potential are not distributed, artists with slightly higher market size distribute their product online, while firms with more intermediate size prefer the P2P technology although they could have used the traditional distribution technology. For instance in Figure 1, artists with $0.8 < \rho < 0.9$ use the online distribution technology although the traditional distribution technology was profitable. Finally firms with a large market size distribute their products traditionally.

INSERT FIGURE 1: $\phi = .15$

INSERT FIGURE 2: $\phi = .3$

Increasing $\phi$ from .15 to .3 has several noticeable effects. First, the range of $\rho$ that supports the traditional distribution technology increases. Secondly some firms switch from the P2P technology to the traditional distribution technology. Thirdly, the minimum size to enter the market using P2P increases too. Thus there are fewer firms in the market and a more important fraction chooses the traditional distribution technology. Thus the overall change in profits in the industry after an increase in copyright protection will depend on the distribution of firm audiences $\rho$. Let $g(\rho)$ denote the density of firm audiences and assume no price competition. When $g'(\rho) > 0$ (so that there are more firms with a large audience, or superstars), we can expect an increase in the total incentives to create original work. If $g'(\rho) < 0$ (with a larger number of small firms), total profits in the industry can be expected to decrease.
4 Discussion and extensions

Subscription based business models. There are other types of legal arrangements that could be considered when dealing with online piracy. First, the traditional distributor could enforce a law prohibiting P2P technologies so that all digital copies would be under his control, or he could discriminate between both types of consumers by offering upgraded and downgraded versions of the same product. Second, a legal arrangement could force existing distributors to play the role of the P2P technology by distributing new artists online. Again, it is interesting to determine the optimal access fee charged by the distributor to the newcomers as well as the price paid by consumers who do not mind spending time online.

Quality production. We have shown that one of the critical welfare determinant is the degree of differentiation between originals and copies and how it relates to legal and technical protection. In order to maximize the incentive to create, producers could improve the quality of the original by offering a number of features that could not appear on the copy: a booklet containing lyrics, pictures, or an access code to online chat rooms, forums, making-offs, additional music and live performances (etc.). Indeed, the possibility to offer an internet connection with login and password to a site with additional features for purchasers of original products illustrates the possibility to make digital products rival, in which case the upgraded product can be assimilated to a private good. Another way to increase the value of the original is to tie or bundle it with excludable and rival products such as merchandizing and live concerts. This situation is even more interesting if we separate the artists and the distributor in a vertical relation. Indeed, a consequence of the bundling could well be that the negotiation power between labels and artists shifts towards artists. They could even increase the royalties. In any case, we can expect a change of market structure.

Note that in the model, a firm distributing its product online can not survive when there is no quality difference between the original and the copy. On the contrary, firms distributing their products traditionally can survive
when $\gamma(0) = 0$. Thus firms using online distribution technologies have more incentives to increase quality than the other type of firms.

*Informational intermediaries.* We also assumed that digital copies provide information on the existence and the characteristics of new products. However, it is foreseeable that as a growing number of new products becomes available, consumers will ignore the existence of one particular product they could have a potential interest in. We believe that new distribution technologies could open the market for informational intermediaries. Indeed, in our model, both distribution technologies are informationally inefficient. On the one hand, the firm using the traditional distribution technology wastes the fixed cost of advertisement and promotion on reaching consumers with no interest in the music. On the other hand, some consumers using the P2p technology waste resources on downloading music files they do not like. Informational intermediaries could reduce these informational inefficiencies, by promoting and recommending new products, targeting only consumers who have the highest likelihood to purchase the original.

5 Conclusion

Our stylized model shows that strengthening copyright protection can have indirect negative effects on social welfare, when technical protection of original products can be implemented. First, regardless of the distribution technology, buyers’s surplus always decrease. This is due to the indirect effects of copyright protection on prices and technical protection. Secondly, increasing copyright protection benefits firms using traditional distribution technologies and spending resources to inform consumers. On the other hand, increasing copyright protection hurt firms that distribute their products online as it reduces the size of the their potential demand. Finally, we have shown in a parametric example that firms with a small audience can enter the market by distributing their products online and that firms with an intermediate audience prefer to save the fixed cost of marketing of the traditional distri-
buition technology by also distributing their products online. Only firms with a large audience choose to distribute their products traditionally. Thus the total effects of increasing copyright protection on the profits of the industry is ambiguous. In conclusion, increasing copyright protection could shift too much the balance between consumers and copyright owners in favor of firms with a large audience in the digital era.
6 Bibliography


Holm, H.J., 2000, ”The Computer Generation’s Williness to Pay for Originals when Pirates are Present - A CV Study”, *Mimeo.*


7 Appendix

7.1 Proof of Proposition 3

(i) We have $u(0, 1) = v_c(\alpha) - s - \phi$. Since $\frac{dv_c^*}{d\phi} \geq 0$ by Proposition 1 and $v_c'(\alpha) \leq 0$, $v_c(\alpha)$ decreases as $\phi$ increases, so that $u(0, 1)$ also decreases.

(ii) By definition $u(1, 0) = v_b(\alpha) - p$. Since $\frac{dv_b^*}{d\phi} \geq 0$ by Proposition 2 and $v_b' \leq 0$, $u(1, 0)$ decreases as $\phi$ increases.

(iii) Let $\phi_1 < \phi_2$. By Proposition 2, $\hat{s}(\phi_1) > \hat{s}(\phi_2)$. Consumers who switch from the copy to the original have a surplus variation of $\frac{\rho}{s} \int_{\hat{s}(\phi_2)}^{\hat{s}(\phi_1)} (v_b(\phi)2 - p(\phi_2) - v_c(\phi_1) + s + \phi_1) ds = \frac{\rho}{s} (\hat{s}(\phi_1) - \hat{s}(\phi_2)) (v_b(\phi_2) - v_b(\phi_1) + v_c(\phi_2) - v_c(\phi_1) + \phi_1 - \phi_2 + p(\phi_1) - p(\phi_2))$. Since $v_c$ is an decreasing function of $\phi$ and $p$ is an increasing function of $\phi$, the surplus variation is negative.

In the following two proofs, we need to make an assumption on the convexity of $v_c$ in order to have a concave program: $\gamma \frac{\rho^2}{s^2} v_c'' < c''$.

7.2 Proof of Proposition 5

The Lagrangian of the optimization program is

$$L = p \frac{\rho}{s} (\rho v_c - \phi) - c + \lambda (\gamma - p) + \mu (\rho v_c - \phi)$$

where $\lambda > 0$ and $\mu > 0$ are the multipliers associated with the two constraints. When the second constraint is binding the optimal solution is to set $p^* = \gamma (\alpha^*)$ and $\alpha^* = \overline{\alpha}$, where $\overline{\alpha}$ is such that $\rho v_c(\overline{\alpha}) = \phi$. Because implementing technical protection is costly and leads to a zero demand, the profits are negative. When the second constraint is not binding, $\mu = 0$. The first order conditions are

$$\frac{\partial L}{\partial p} = \frac{\rho}{s} (\rho v_c - \phi) - \lambda = 0$$

$$\frac{\partial L}{\partial \alpha} = p \frac{\rho^2}{s} v_c' - c' + \lambda \gamma' = 0$$

$$(\gamma - p) \lambda = 0$$

Because the Lagrangian is increasing in $p$, it is optimal to saturate the first constraint and set $p^* = \gamma (\alpha)$. Substituting the value of $\lambda$ defined by the first first-order
condition into the second yields Lemma 1. In order to have a maximum, we need to check the second order derivative of the Lagrangian with respect to \( \alpha \):

\[
\frac{\partial^2 L}{\partial \alpha^2} = \beta \frac{\rho^2}{S} v_c'' - c'' + \lambda \gamma''
\]

Since by assumption \( \gamma'' < 0 \), a sufficient condition to have \( \frac{\partial^2 L}{\partial \alpha^2} < 0 \) at the optimum is \( \gamma \frac{\rho^2}{S} v_c'' < c'' \), which is the assumption stated before. Now, applying the implicit function theorem to \( F(\alpha, \phi) = 0 \) defined in Lemma 1, we obtain that \( \frac{\partial \alpha}{\partial \phi} = \frac{-\frac{\partial F}{\partial \alpha}}{\frac{\partial F}{\partial \phi}} \). Since the numerator is positive, it remains to show that the denominator is negative. We have: \( \frac{\partial F}{\partial \alpha} = 2\gamma' v_c' \frac{\rho^2}{S} + \gamma \frac{\rho^2}{S} v_c'' - c'' + \frac{\rho}{S} (\rho v_c - \phi) \gamma'' < 0 \) using our sufficient condition on \( v_c'' \). Thus \( \frac{\partial \alpha}{\partial \phi} < 0 \).

### 7.3 Proof of Proposition 7

We first show that \( \frac{\partial \alpha}{\partial \phi} < 0 \). Straightforward calculations yield:

\[
\frac{\partial \hat{s}}{\partial \phi} = \rho v_c \frac{\partial \alpha}{\partial \phi} - 1 = \rho v_c \frac{\frac{\partial \alpha}{\partial \phi}}{\frac{\partial \beta}{\partial \phi}} - 1
\]

where the second equality follows from the proof of Proposition 5. Substituting the expressions found in the proof of Proposition 5 and rearranging shows that \( \frac{\partial \alpha}{\partial \phi} < 0 \) if \( \gamma' v_c' \frac{\rho^2}{S} + \gamma \frac{\rho^2}{S} v_c'' - c'' + \frac{\rho}{S} (\rho v_c - \phi) \gamma'' < 0 \), which again holds by our assumption on \( v_c'' \).

Let \( \phi_2 > \phi_1 \) without loss of generality.

(i) A proportion \( \hat{s}(\phi_1) - \hat{s}(\phi_2) \) does not copy with \( \phi_2 \) but did so with \( \phi_1 \).

There is a reduction of the number of copiers, which means that there is a smaller proportion of copiers who waste resources on copying without enjoying the product \((1 - \rho) \hat{s}(\phi_1) - \hat{s}(\phi_2))\)

(ii) The surplus of copiers who become purchasers is given by

\[
U_b = \rho \frac{\hat{s}(\phi)}{S} (\rho v_c (\alpha^*(\phi)) - \phi)ds = \rho \frac{\frac{\partial \alpha}{\partial \phi} (\rho v_c (\alpha^*(\phi)) - \phi)}{2}. \]

After rearranging, we obtain that \( \frac{\partial U_b}{\partial \phi} = \frac{\rho}{S} (\rho v_c (\alpha^*(\phi)) - \phi) [\frac{\partial \alpha}{\partial \phi} \frac{\partial \beta}{\partial \phi} - 1] \). The expression in between brackets is precisely \( \frac{\partial \alpha}{\partial \phi} \), which was shown to be negative. Thus \( U_b \) is decreasing in \( \phi \).
Figure 1

Figure 2