Digitalization and Ownership Structure of Private Copy Protection

By

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Abstract

The purpose of this paper is to analyze how digitalization affects pricing and private copy protection in contents industries. Digitalization enables content providers and online retailers to implement copy protection at different stages of creation and distribution of contents. We construct a model of vertical relationship where an upstream [a downstream] firm is considered as a content provider [a retailer]. Three different business models are proposed according to the ownership structure of copy protection determined the right to implement by a vertically-integrated entity, an upstream firm, and a downstream firm. In this setup we show that the results are dependent upon the degree of opportunistic behavior responding to increasing rival (piracy) costs under the different copy protection ownership. In addition, to address the change in demand side with digitalization we consider two different types of piracy differentiated by distribution channels (e.g., non-digital versus digital). We show that the effect of piracy on price and private copy protection depend critically on the nature of distribution channels and the dimension of differentiation between originals and pirated contents. In particular, strengthening IPR protection results in a price hike for the both cases, while we have opposite changes in quantities and the level of copy protection depending on different types of piracy.

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1. Introduction

The effect of piracy on content providers' sales and profits is a controversial issue for economists, policy makers, consumers, and content providers. With the advent of the Internet and digitalization of contents piracy has become a more attractive option for consumers to obtain contents illegally. This, in turn, led content providers and retailers to come up with own protection technologies (i.e., digital rights management (DRM)). Therefore, digitalization has a twofold impact on content industries. On the one hand, digitalization enabled consumers to have more options in obtaining contents which are used for piracy. One option is to use a non-digital distribution channel where consumers obtain the original material through personal contacts and make an illegal copy of the contents. A second option which has emerged with digitalization is to use a digital distribution channel such as a variety of peer-to-peer (P2P) networks.[1] P2P networks do not host files on a central server; instead they list available files on individual PCs and directly connect those computers which are considered to have more profound effect on the usage of content. Digitalization enables content providers and retailers to distribute their contents with better protection and control through implementing private copy protection[2]. These two opposing effects of digitalization on content industries have been analyzed in the literature on piracy[3].

Examples of the different copy protection ownership can be found in various contents industries. The first private copy protection implemented by the record labels in the music industry is Serial Copy Management System (SCMS) as the result of the Audio Home Recording Act of 1992 (AHRA)[4]. SCMS is, for example, designed to have some bits in subcodes in the tape in order to control future copying of the DAT machines. SCMS was implemented into digital audio tape (DAT) machines, MiniDisc recorder and other CD recorders to protect the rights of the copyright holders from illegally copying music. However, by the turn of the Millennium with wide availability of CD burners and MP3 format to consumers, computers have

[1] Similar concepts are used in a study by MPA and LEK (2006) on the behalf of the Motion Picture Association of America (MPAA). The traditional channel is equivalent to "hard good piracy" defined as "obtaining movies by either purchasing or acquiring an illegally produced VHS/DVD/VCD through a commercial source, or making illegal copies for oneself or receiving from a personal source (friend or family) an illegal copy of a legitimate VHS/DVD/VCD"; the P2P piracy is comparable to "Internet piracy" defined as "obtaining movies by either downloading them form the Internet without paying or acquiring hard copies of illegally downloaded moves from friends or family".

[2] This paradoxical feature of digitalization in the music industry was also analyzed in Peitz and Waelbroeck (2005).

[3] For a survey, see Peitz and Waelbroeck (2006).

[4] See Aldrich (2006) for more detailed legal and technical discussion about DRM technology in the music industry.

become the biggest threat to the music industry. Consumers are able to "rip" music from CDs onto computer hard divers and burn other CDs, share them via the Internet. Moreover, computers and MP3 players, which contain the hard driver to store music files, are not subject to the AHRA, which makes the music industry fail to make SCMS compulsory to hard drivers in computers and MP3 players[5].

Failure to implement SCMS in computers and MP3 players leaves no copy protection in music CDs against increasing popularity of P2P file sharing among consumers. Some record labels have been testing different types of protection technology in order to protect their contents from piracy. For example, record labels intent to introduce new 'copy control' CDs. Sony BMG was trying to introduce new DRM systems called the Extended Copy Protection (XCP2) from First 4 Internets and MediaMax CD-3 software from SunnComm on music CDs designed to prevent illegal copy of music CDs. Another record label EMI has been testing copy protection called CDS-300 from Macrovision. The aim of these copy technologies is to limit the number of copies consumers make from his purchased CDs on computers. However, these DRM technologies turned out to be not only less effective to deter piracy compared to SCMS but also to have compatibility issues with CD players[6] and security problems[7].

Other attempts to prevent piracy were initiated not by record labels but by online retailers. In 2003, for instance, Apple Computer opened the iTunes Music Store, an online retailer with 200,000 songs available for downloads at lower prices compared to these of CDs. The downloaded songs from iTunes have DRM called Fairplay to restrict usage of songs. Fairplay DRM restricts user's usage of the downloaded music flies in such a way allowing to burn a playlist seven times and to transfer music files up to five computers, etc. Other online music stores such as Napster and Rhapsody provide fee based subscription service of music with Windows Media DRM. These subscription services crucially depend on the successful DRM to deter intertemporal arbitration since users never renew their services if saving of streaming files

[5] Recording Industry Association of America v. Diamond Multimedia Systems, Inc., 180 F.3d 1072, 1079 (9th Cir. 1999).

[6] A French consumer association UFC-Que Choisir filed a law suit against EMI claiming that some copy protected music CDs are not compatible with car stereos, hi-fi's and personal computers (Frost, 2004).

[7] XCP2 containing a rootkit was automatically installed on Windows desktop computers when customers tried to play the CDs. The software interferes with the normal way in which the Microsoft Windows operating system plays CDs, opening security holes that allow viruses to break in, and causing other problems.

on their portable players is possible. The above examples show the change in the ownership structure of copy protection in the music industry responding to digitalization.

Learning a lesson from the experience of the music industry the movie industry took a cautious step to introduce DVD format around 1997. In the movie industry the examples of the control over DRM by the upstream content providers are Content Scrambling System (CSS) and Advanced Access Content System (AACS). CSS is a DRM system with encryption to protect DVD content from illegal copying controlled by a consortium of entertainment and technology companies called the DVD Copy Control Association[8]. More recently, AACS is a new DRM system for HD DVD and Blu-Ray Discs developed by the AACS Licensing Administrator, LLC (AACS LA); a consortium including some movie studios. With similar fashion, digitalization facilitates online retailers to provide digital format of movies via internet with DRM. For example the two major online movie retailers CinemaNow and Movielink use PatchBay and Windows Media DRM respectively to restrict the usage of downloaded movies[9].

The purpose of this paper is to provide a simple theoretical framework explaining how digitalization of contents influences consumer's piracy behavior and firms' optimal choice of the level of private copy protection and prices. In order to properly address the different types of private copy protection implemented either by content providers or online retailers we introduce an upstream-downstream model. Within this framework three different business models are developed according to the ownership structure of private copy protection which determines the right to implement; a vertically integrated entity as a benchmark, content providers (i.e., CSS, SCMS) and online retailers (i.e., FairPlay, PatchBay). Given these three business models we further categorize them according to types of piracy determined by different distribution channels (i.e., digital vs. non-digital). With different combination of the ownership of private copy protection and types of piracy, we consider three possible regimes [see table 1 and figure 1]. The first regime is termed "vertically differentiated piracy (VDP) regime I." In this regime the offline retailer sells non-digital content facing non-digital piracy and the private copy protection ownership belongs to the content providers. Since consumers face the same format of piracy we assume that the dimension of differentiation between an original and a pirated content is

[8] For detailed discussion about different types of control of piracy associated with different types of piracy in the movie industry see Waterman et al. (2007).

[9] The services from these online retailers include Pay-Per-View, Download-to-own and recently Burn-to-DVD. The last services adopted by CinemaNow and Movielink in 2007 also has DRM to allow consumers burn a downloaded movie only once to a blank DVD.

vertically differentiated and the pirated content is imperfect substitute to the original. The second regime "VDP regime II," is where the online retailer who controls private copy protection sells a digital content facing digital piracy of the same format which is vertically differentiated. Therefore, the difference between two regimes I and II resides in the ownership of private copy protection. These assumptions of vertically differentiated inferior substitute are commonly adopted in the most theoretical literature on piracy.

The third regime termed "vertically and horizontally differentiated piracy (VHDP) regime depicts a situation where non-digital contents equipped with private copy protection implemented by a content provider are sold at an offline retailer facing digital piracy. This regime incorporates users' self selection of formats represented by heterogeneous tastes towards digitalization among consumers depending on, for example, propensity to use internet, knowledge about file sharing networks, age and income, etc[10].

The impact of digitalization in terms of the different ownership structure of private copy protection is captured by comparing the optimal level of private copy protection and prices under the regimes VDP (I) and VDP (II). The highest level of private copy protection is chosen by the vertically integrated firm. The next highest level is the one chosen by the downstream retailer. The lowest is the level chosen by the upstream content provider. Also, the incentive to block piracy is consistent with the order of the level of private copy protection. It is shown that the results are dependent upon the ownership structure of private copy protection and the degree of opportunistic behavior responding to increasing rival (piracy) costs. Next, we analyze the impact of digitalization in terms of types of piracy with different distribution channels. A comparison between VDP (I) and VHDP regimes shows that the effect of piracy depends critically on the nature of distribution channels and dimension of product differentiation. In particular, strengthening IPR protection results in price hike in the two cases, while we have opposite changes in quantities depending on different types of piracy.

[10] Similarly, Peitz and Waelbroeck (2005) propose the different attributes of consumers such as "early adopters" and "late adopters" to explain the decline in CD sales. Their argument is based on the fact that tech-savvy young generations who are early adopters have high propensity to use P2P websites while older users tend to be late adopters due to higher purchasing power and opportunity cost to use P2P websites. Also, Boorstin (2004) finds the negative relationship between ages and CD purchase with implicit assumption that internet usage is a good measure of piracy behavior.

The organization of the paper is as follows. In section 2 we formulate the basic two tier model with presence of piracy which has the same format as the original content and analyze the equilibrium accommodation and limit pricing outcomes under different assumptions about the ownership structure of private copy protection. In section 3 we introduce piracy in a digital format in the framework of Hotelling's linear city model to analyze the effect of piracy in different format on price, the level of private copy protection, and profits of the content provider and the retailer who sells non-digital contents. Comparative statics results are discussed in section 4. The last section concludes.

2. Vertically differentiated piracy regimes (VDP I and II)

Consider a two-tier market for content developed by a monopoly content provider (upstream firm) with a single retailer (downstream firm). Consumers are heterogeneous in their valuation of content such as music, movies, computer software, etc[11]. The number of consumers is normalized to 1 and they are uniformly distributed on the unit interval [0, 1]. The retailer is assumed to be of selling the content and is located at point 0. Let v be the basic value each user attaches to the content and is assumed to be 1 for analytical simplicity. The gross utility is denoted by $v - tx_i$ which can be viewed as a lineup of consumers whose valuation decreases as being further away from point 0. The parameter t measures a marginal decrease in consumer's willingness to pay and is assumed to be 1 without loss of generality. Each consumer is assumed to purchase at most one unit of the content. Therefore, the utility of buying an authorized content is given by

$$U(x_i) \overset{def}{=} \begin{cases} (v - tx_i) - p = (1 - x_i) - p & \text{if he/she buys the content} \\ 0 & \text{if he/she does not buy the content} \end{cases} \quad (1)$$

where p is the price of one unit of the content charged by the downstream retailer.

We now introduce the possibility of using the content through piracy without purchasing a legal product. In this case the consumer can save the price but incurs the following two costs. First, consumers are assumed to suffer loss of valuation by $\alpha(1 - x_i)$ with $\alpha \in (0,1)$ measures the degree of quality degradation because the pirated good is assumed to be imperfect substitute

[11] We should emphasize here that consumers are heterogeneous in their valuation of the content, which is corresponding to vertical differentiation. Heterogeneity of consumers in terms of their preference towards formats, which is corresponding to horizontal differentiation, is later introduced in Section 3.

to the original. This gives the pirated content a valuation of $(1-\alpha)(1-x_i)$. In addition, we assume that consumers also face reproduction cost *(e)* when making an illegal reproduction (Bae and Choi, 2006). The reproduction cost includes the physical cost (e.g., CDs to hold illegally copied contents and the space in hard drivers) and the search and learning cost to find hacking technology to bypass the copy protection system of the content. Since the physical cost is close to negligible, the reproduction cost generally means the search and learning cost. In our model, the reproduction cost is determined by the level of private copy protection since the reproduction cost is positively correlated with the level of copy protection because consumers need more time to search and learn hacking technology since hackers need to make more efforts to hack the copy protection system. Therefore, private copy protection, which corresponds to the reproduction cost, is endogenously determined by either the content provider or the retailer. Thus, the utility of using an unauthorized copy is given by

$$U(x_i) \overset{def}{=} (1-\alpha)(1-x_i) - e \tag{2}.$$

Given three options to use the content (i.e., buying the original, making an illegal copy, and no use), there are two marginal consumers, x_1 and x_2. We denote x_1 as the marginal consumer who is indifferent between buying the original and making an illegal copy. Similarly, x_2 is denoted as the marginal consumer who is indifferent between making an illegal copy and no use of the content.

Given definitions of two marginal consumers we represent them as follows:

$$(1-x_1) - p \equiv (1-\alpha)(1-x_1) - e \Rightarrow x_1 = \frac{\alpha + e - p}{\alpha}$$

$$(1-\alpha)(1-x_2) - e \equiv 0 \Rightarrow x_2 = 1 - \frac{e}{1-\alpha}.$$

Given the configuration of two marginal consumers we restrict our attention to the parameter regions in which the piracy constraint is binding, that is,

$$x_1 \le x_2 \Rightarrow p \ge \frac{e}{1-\alpha} \tag{3}$$

When the piracy constraint is binding, the demand faced by the downstream retailer determines how the retailer responds to piracy: accommodation or limit pricing. When the retailer chooses

to implement the limit price should be given by $p^L = \frac{e^L}{1-\alpha}$ to eliminate the incentive to copy.[12] Another option for the retailer is to charge a price $p > p^L$ such that some consumers are better off with using the illegal content. The retailer's demand functions under the different regimes are given by

$$q(p,e) = \begin{cases} \frac{\alpha + e - p}{\alpha} & \text{under the accommodation regime} \\ 1 - \frac{e^L}{1-\alpha} & \text{under the limit pricing regime} \end{cases} \tag{4}$$

Given demand structure the subgame perfect nash equilibrium is specified by the price, copy protection and the licensing fee (wholesale price) denoted by a triplet (p_j, e_j, w_j) with $j = \{vi, cp, r\}$ where *vi, cp, r* are abbreviations of vertical integration, content provider and retailer, respectively. The structure of the two-stage game is slightly different depending on who owns the control over copy protection. When the upstream content provider has control over copy protection the wholesale price and copy protection level are determined by the content provider in the first period. After observing the content provider's strategy the downstream retailer sets its retail price of the content. On the other hand, the content provider is only able to choose the licensing fee at the first stage in the case where control over copy protection and price belongs to the downstream retailer. At the end of the second stage consumers make their usage decision under both regimes. The timing of the two-stage game under different regimes is summarized in table 2.

2.1. Benchmark case: vertical integration

We now turn to the vertically integrated monopolist's optimal choice of its price and DRM (p_{vi}, e_{vi}) when the piracy constraint is binding $\left(\frac{e_{vi}}{1-\alpha} < p_{vi}\right)$. The first option for the monopolist is to accommodate piracy in which the monopolist sets a higher price and tolerates copying. In this case, the monopolist's objective becomes:

$$\underset{p_{vi}, e_{vi}}{Max}\, \pi_{vi} = p_{vi} \cdot q(p_{vi}, e_{vi}) - C(e_{vi}) \tag{5}$$

[12] Variables under the limit pricing regime are denoted by a superscript *L*

where we use $C(e) \overset{def}{=} \frac{c}{2}e^2 + K$ to represent monopolist's cost function to create its own copy protection (i.e., DRM) for its content. Specifically, *K* is the fixed cost of creating its copy protection, and the parameter *c* represents the marginal cost of copy protection. We use this form of cost function in order to simplify subsequent calculation and to have interior solutions. The first order conditions with respect to p_{vi} and e_{vi} are given by

$$\frac{\partial \pi_{vi}}{\partial p_{vi}} = q_{vi}\left(p_{vi}, e_{vi}\right) + p_{vi}\frac{\partial q_{vi}}{\partial p_{vi}} = 0 \tag{6}$$

$$\frac{\partial \pi_{vi}}{\partial e_{vi}} = p_{vi}\frac{\partial q_{vi}}{\partial e_{vi}} - C'\left(e_{vi}\right) = 0 \tag{7}$$

Solving eq. (6) and (7) together gives the equilibrium of the vertically integrated monopoly:

$$\left\{p_{vi}^*, e_{vi}^*, q_{vi}^*, \pi_{vi}^*\right\} = \left\{\frac{\alpha^2 c}{2\alpha c - 1}, \frac{\alpha}{2\alpha c - 1}, \frac{\alpha c}{2\alpha c - 1}, \frac{\alpha^2 c}{2\left(2\alpha c - 1\right)}\right\} \tag{8}$$

The second option for the monopolist is to eliminate piracy by setting the price sufficiently low. Since the monopolist would reduce the price until the piracy constraint is binding, $(1-\alpha)(1-x_i) - e_{vi}^L = (1-x_i) - p_{vi}^L$, the limit price satisfies the constraint to eliminate the incentive to copy. The optimal limit price that prevents the incentive to copy is given by

$$p_{vi}^L = \frac{e_{vi}^L}{1-\alpha} \tag{9}.$$

The first order condition with respect to e_{vi}^L

$$\frac{\partial \pi_{vi}^L}{\partial e_{vi}^L} = \frac{1-\alpha-2e_{vi}^L}{\left(1-\alpha\right)^2} - ce_{vi}^L = 0\,, \tag{10}$$

gives us the results under limit pricing:

$$\left\{p_{vi}^{L*}, e_{vi}^{L*}, \pi_{vi}^{L*}\right\} = \left\{\frac{1}{2+c\left(1-\alpha\right)^2}, \frac{1-a}{2+c\left(1-a\right)^2}, \frac{1}{2\left(2+c\left(1-\alpha\right)^2\right)}\right\} \tag{11}.$$

By comparing profits from each strategy, we conclude that the monopolist's optimal choice is to accommodate piracy if $c > \frac{1}{\alpha\left(1-\alpha\right)} \equiv \overline{c}_{vi}$ and to limit price if $c \le \overline{c}_{vi}$ where $\overline{c}_{vi}$ denotes the upper boundary of *c* where the monopoly is enabled to eliminate piracy.

2.2 Upstream control over DRM

We now introduce the vertical market structure where the upstream firm still controls its licensing fee and copy protection in the first period, while the downstream retailer is assumed to choose its retail price independently in the second period. By backward induction, proceed with the retailer's optimal choice of pricing in the second period. The downstream retailer decides between accommodation and limit pricing strategies based on the realized copy protection and the licensing fee. The retailer's profits π_{cp}^{d} under each regime are given in the following equation.

$$\pi_{cp}^{d} = \left(p_{cp} - w_{cp}\right) q_{cp} = \begin{cases} \left(p_{cp} - w_{cp}\right)\left(\dfrac{\alpha + e_{cp} - p_{cp}}{\alpha}\right) & \text{accommodate if } \dfrac{e_{cp}}{1-\alpha} < p_{cp} \\ \left(\dfrac{e_{cp}^{L}}{1-\alpha} - w_{cp}^{L}\right)\left(1 - \dfrac{e_{cp}^{L}}{1-\alpha}\right) & \text{limit pricing if } \dfrac{e_{cp}}{1-\alpha} \geq p_{cp} \end{cases} \tag{12}$$

The first order condition with respect to p_{cp} under the accommodation regime gives us

$$\frac{\partial \pi_{cp}^{d}}{\partial p_{cp}} = 1 - \frac{p_{cp} - e_{cp}}{\alpha} - \frac{p_{cp} - w_{cp}}{\alpha} = 0 \tag{13}$$

which yields $p_{cp}^{*} = \frac{1}{2}\left(\alpha + e_{cp} + w_{cp}\right)$. Comparing the profit function under two regimes the downstream retailer's optimal prices are given by

$$p_{cp}^{*} = \begin{cases} \dfrac{1}{2}\left(\alpha + e_{cp} + w_{cp}\right) & \text{if } e_{cp} < \dfrac{\left(1-\alpha\right)\left(\alpha + w_{cp}\right)}{\left(1+\alpha\right)} \\ \dfrac{e_{cp}^{L}}{1-\alpha} & \text{if } e_{cp} \geq \dfrac{\left(1-\alpha\right)\left(\alpha + w_{cp}^{L}\right)}{\left(1+\alpha\right)} \end{cases} \tag{14}$$

In the first stage the upstream content provider has two options: making the downstream firm adopt accommodation by setting $\left(w_{cp}, e_{cp}\right)$ to satisfy $e_{cp} < \dfrac{\left(1-\alpha\right)\left(\alpha + w_{cp}\right)}{\left(1+\alpha\right)}$ or implement the

limit pricing with the constraint $e_{cp}^{L} \geq \frac{(1-\alpha)(\alpha + w_{cp}^{L})}{(1+\alpha)}$. Under the accommodation regime the content provider maximizes the following profit function:

$$\underset{p_{cp}}{Max}\, \pi_{cp}^{u} = w_{cp} \cdot q_{cp}(e_{cp}) - C(e_{cp}).$$

Setting the first derivatives with respect to w_{cp} and e_{cp} to zero gives us the following equilibrium values:

$$\left\{p_{cp}^{*}, e_{cp}^{*}, q_{cp}^{*}, w_{cp}^{*}\right\} = \left\{\frac{3\alpha^2 c}{4\alpha c - 1}, \frac{\alpha}{4\alpha c - 1}, \frac{\alpha c}{4\alpha c - 1}, \frac{2\alpha^2 c}{4\alpha c - 1}\right\} \text{ and}$$

$$\left\{\pi_{cp}^{u*}, \pi_{cp}^{d*}\right\} = \left\{\frac{\alpha^2 c}{2(4\alpha c - 1)}, \frac{\alpha^3 c^2}{(4\alpha c - 1)^2}\right\} \tag{15}$$

On the other hand, the upstream firm's choice is to make the downstream firm implement the limit pricing to maximize the following profit function:

$$\underset{p_{cp}}{Max}\, \pi_{cp}^{uL} = w_{cp}^{L} \cdot q_{cp}^{L} - C(e_{cp}^{L}) \text{ subject to } e_{cp}^{L} = \frac{(1-\alpha)(\alpha + w_{cp}^{L})}{(1+\alpha)}, \text{ which gives us}$$

$$\left\{p_{cp}^{L*}, e_{cp}^{L*}, q_{cp}^{L*}, w_{cp}^{L*}\right\} = \left\{\frac{1}{\Delta}(1+2\alpha), \frac{1}{\Delta}(1+\alpha-2\alpha^2), \frac{1}{\Delta}\left(1+c(1-\alpha)^2\right), \frac{1}{\Delta}\left(1+2\alpha(1-\alpha)^2 c\right)\right\} \text{ and}$$

$$\left\{\pi_{cp}^{uL*}, \pi_{cp}^{dL*}\right\} = \left\{\frac{1}{\Delta^2}\left(1-2\alpha c(1-\alpha)^2\right), \frac{1}{2\Delta}\left(\alpha\left(1+c(1-\alpha)^2\right)^2\right)\right\} \text{ where } \Delta = c(1-\alpha)^2 + 2(1+\alpha) \tag{16}.$$

By comparing profits from each strategy, we conclude that the optimal choice of the upstream firm is to accommodate piracy if $c > \frac{1}{3\alpha(1-\alpha)} \equiv \overline{c}_{cp}$ and to limit price if $c \leq \overline{c}_{cp}$.

2.3. Downstream control over copy protection

By backward induction, the downstream retailer chooses its price and copy protection $\{p_r, e_r\}$ to maximize

$$\underset{\{p_r, e_r\}}{Max}\, \pi_{r}^{d} = (p_r - w_r) q_r(p_r, e_r) - C(e_r) \tag{17}.$$

The first order conditions with respect to $\{p_r, e_r\}$

$$\frac{\partial \pi_r^d}{\partial p_r} = q_r\left(p_r, e_r\right) + \left(p_r - w_r\right)\frac{\partial q_r}{\partial p_r} = 0 \tag{18},$$

$$\frac{\partial \pi_r^d}{\partial e_r} = \left(p_r - w_r\right)\frac{\partial q_r}{\partial e_r} - C'\left(e_r\right) = 0 \tag{19}$$

$$\text{yields } \left\{p_r^*, e_r^*\right\} = \begin{cases} \left\{\dfrac{\left(1-\alpha c\right)w_r - \alpha^2 c}{2\alpha c - 1}, \dfrac{w_r - \alpha}{2\alpha c - 1}\right\} & \text{if } w_r > \dfrac{1+\alpha c\left(1-\alpha\right)}{1+c-\alpha c} \\ \left\{\dfrac{1+w_r^L}{2+c\left(1-\alpha\right)^2}, \dfrac{\left(1-\alpha\right)\left(1+w_r^L\right)}{2+c\left(1-\alpha\right)^2}\right\} & \text{if } w_r \le \dfrac{1+\alpha c\left(1-\alpha\right)}{1+c-\alpha c} \end{cases} \tag{20}.$$

In the first stage the upstream content provider sets w_r to maximize $\pi_r^u = w_r q_r$. Solving the first order condition we obtain the equilibrium input price. Substituting w_r into $\left\{p_r, e_r\right\}$ gives the following equilibrium values:

$$\left\{p_r^*, e_r^*, q_r^*, w_r^*\right\} = \left\{\frac{\alpha\left(3\alpha c - 1\right)}{2\left(2\alpha c - 1\right)}, \frac{\alpha}{2\left(2\alpha c - 1\right)}, \frac{\alpha c}{2\left(2\alpha c - 1\right)}, \frac{\alpha}{2}\right\} \text{ and}$$

$$\left\{\pi_r^{u*}, \pi_r^{d*}\right\} = \left\{\frac{\alpha^2 c}{4\left(2\alpha c - 1\right)}, \frac{\alpha^2 c}{8\left(2\alpha c - 1\right)}\right\} \tag{21}.$$

On the other hand, the upstream's choice is to make the downstream implement the limit pricing to maximize the following profit function: $\underset{w_r}{Max}\, \pi_r^{uL} = w_r^L q_r^L$ with

$w_r^L = \dfrac{1+\alpha c\left(1-\alpha\right)}{1+c-\alpha c}$ giving us the following equilibrium values under the limit pricing:

$$\left\{p_r^{L*}, e_r^{L*}, q_r^{L*}, w_r^{L*}\right\} = \left\{\frac{1}{1+c-\alpha c}, \frac{1-\alpha}{1+c-\alpha c}, \frac{c\left(1-\alpha\right)}{1+c-\alpha c}, \frac{1-\alpha c\left(1-\alpha\right)}{1+c-\alpha c}\right\} \text{ and}$$

$$\left\{\pi_r^{uL*}, \pi_r^{dL*}\right\} = \left\{\frac{1-\alpha c\left(1-\alpha\right)}{\left(1+c-\alpha c\right)^2}, \frac{c\left(1-\alpha\right)^2\left(2\alpha c - 1\right)}{2\left(1+c-\alpha c\right)^2}\right\} \tag{22}.$$

By comparing profits from each strategy, we conclude that the content provider's optimal choice is to accommodate piracy if $c > \dfrac{2-\alpha}{3\alpha\left(1-\alpha\right)} \equiv \bar{c}_r$ and to limit price if $c \le \bar{c}_r$.

Proposition 1 The optimal pricing and the level of copy protection across different ownership structure of copy protection are shown as follows:

1) $e_{vi}^* > e_r^* > e_{cp}^*$

2) $p_{cp}^* > p_r^* > p_{vi}^*$ and $w_{cp}^* > w_r^* > w_{vi}^* = 0$ with $\frac{p_{cp} - w_{cp}}{p_{cp}} < \frac{p_r - w_r}{p_r}$

3) $\overline{c}_{vi} > \overline{c}_r > \overline{c}_{cp}$

A fuller explanation of Proposition 1 is as follows. In the two-tier model regardless of whoever a firm chooses to implement copy protection, it is not efficient to reduce piracy compared to the choice of the vertically integrated monopoly due to the existence of opportunistic behavior. For instance, when the content provider sets a higher level of copy protection, it is equivalent to an outward parallel shift in demand for the retailer. With increased demand there exists opportunistic behavior of the downstream retailer to respond with a price hike. The price increase, however, does not completely offset the initial demand increase with the result of increased sales. Therefore, the incentive for the content provider to provide stronger copy protection is reduced. On the other hand, in the case of retailer control over copy protection, we find that the optimal level of copy protection chosen by the downstream retailer is higher than that by the upstream content provider. Since the upstream licensing fee is chosen before the downstream copy protection, it eliminates the possible upward adjustment of the licensing fee by the content provider, which hampers the retailer's incentive to invest in copy protection. However, the level of copy protection under R regime is still lower than under VI regime due to double monopolization. This phenomenon can be viewed as the downstream firm's R&D incentive to raising the rival's cost via increasing demand for inputs. Since the retailer's investment in copy protection to raise the copy cost is determined after the upstream firm's choice of the licensing fee, it eliminates the negative effect of an upward adjustment of input price on R&D. As a result, the highest level of copy protection is chosen by the vertically integrated firm. The next highest level is the one chosen by the downstream retailer. The lowest is the level chosen by the upstream content provider. The incentive to eliminate piracy represented by the upper boundary of *c* shows similar intuition. Since opportunistic behavior of the downstream retailer exists under CP regime copy protection technology should be very efficient to eliminate piracy compared to the case under R regime.

Examples of proposition 1 can be found in the music and movie industries. Before digitalization the most prevailing business form of distributing contents is hard good distribution by offline retailers. The content providers implement copy protection (i.e., SCMS, CSS) to protect their contents against non-digital piracy. The new roles of the downstream after digitalization are not only to distribute contents digitally but also to implement its own DRM (i.e., FairPlay, PatchBay) in order to eliminate digital piracy. These structural changes result in the advent of legal distribution channels of digital contents at a lower price with more sophisticated copy protection and the increased market share of digital distribution. We also observe the power shift from the content providers to the retailers. The comparison of relative margin between two regimes reveals that online retailer's share has been increased[13].

3. Vertically and horizontally differentiated priacy (VHDP) regime

We now introduce different type of piracy where the non-digital content provider faces digital piracy. Similar to Gayer and Shy (2003), we adopt Hotelling's linear city model to incorporate consumer's different valuation towards digitalization. The retailer is assumed to sell a traditional form of contents (i.e., CD, DVD) and locates at point 0. We assume that there exists a P2P network where consumers can obtain an illegal copy of the digitalized content and locates at point 1. Products from the retailer contain the exact same contents but their formats are assumed to be different. With this setting consumers view content with different formats horizontally differentiated in terms of consumer preference towards different formats, which is represented by the location of consumers. To be consistent with the model in the previous section, a consumer whose location is x_i receives $v - tx_i$ in the non-digital and $v - t(1 - x_i)$ in digital format, respectively. When the consumer chooses digital format only, the pirated content is available so that his utility is reduced by $\alpha\left(v - t(1 - x_i)\right)$. Therefore consumer location x_i measures both a user's willingness to pay for the extra quality provided by an original and his preference towards digital format. Therefore, a type-x_i consumer's utility with normalization of *v* and *t* equal to one is given by

[13] The margin of retailer of CD in Euro area, for example, is 2 to 2.5 Euros per CD on the average with the average price of a CD is 17 Euros (IFPI, 2004). On the other hand, iTunes keeps 29 cents out of 99 cents per one song from Universal Music (Grover and Burrows, 2007).

$$U(x_i) \overset{def}{=} \begin{cases} (v - tx_i) - p = (1 - x_i) - p & \text{if he/she buys the non-digital format} \\ (1-\alpha)(v - t(1 - x_i)) - e = (1-\alpha)x_i - e & \text{if he/she copys the digital format} \end{cases} \quad (23)$$

Given two options to use the content, we denote x_3 as the marginal consumer who is indifferent between buying the original and making an illegal copy. Given the definition of the marginal consumer x_3 we represent him/her as follows:

$$(1 - x_3) - p \equiv (1-\alpha)x_3 - e \Rightarrow x_3 = \frac{1 + e - p}{2 - \alpha}.$$

Given the configuration of the marginal consumer we restrict our attention to the parameter regions in which the piracy constraint is binding, that is,

$$x_3 \leq 1 \Rightarrow p \geq e + \alpha - 1 \quad (24)$$

When the piracy constraint is binding, the demand faced by the downstream retailer determines how the retailer responds to piracy: accommodation or limit pricing. When the retailer chooses to eliminate piracy the limit price is $\tilde{p}^L = \tilde{e} + \tilde{\alpha} - 1$ which eliminates the incentive to copy.[14] Another option for the retailer is to charge a price $\tilde{p} > \tilde{p}^L$ such that some consumers are better off using the illegal content. The retailer's demand functions under the different regimes are given by

$$\tilde{q}(\tilde{p}, \tilde{e}) = \begin{cases} \dfrac{1 + \tilde{e} - \tilde{p}}{2 - \alpha} & \text{under the accommodation regime} \\ 1 & \text{under the limit pricing regime} \end{cases} \quad (25)$$

We consider a two-stage game where the upstream firm still controls its licensing fee and copy protection in the first period, while the downstream retailer is assumed to choose its retail price independently in the second period. By backward induction, proceed with the retailer's optimal choice of pricing in the second period. The downstream retailer decides between accommodation and limit pricing strategies based on the realized copy protection and the licensing fee. The retailer's profits under each regime are given in the following equation.

$$\tilde{\pi}_{cp} = (\tilde{p}_{cp} - \tilde{w}_{cp})\tilde{q}_{cp} = \begin{cases} (\tilde{p}_{cp} - \tilde{w}_{cp})\left(\dfrac{1 + \tilde{e} - \tilde{p}}{2 - \alpha}\right) & \text{accommodate if } \tilde{p}_{cp} > \tilde{e}_{cp} + \alpha - 1 \\ (\tilde{e}^L_{cp} - 1 + \alpha - \tilde{w}^L_{cp}) & \text{limit pricing if } \tilde{p}_{cp} \leq \tilde{e}_{cp} + \alpha - 1 \end{cases} \quad (26)$$

[14] Variables associated with piracy through digital distribution channels are denoted by a tilde.

The first order condition with respect to p_{cp} under the accommodation regime gives us

$$\frac{\partial \tilde{\pi}_{cp}}{\partial \tilde{p}_{cp}} = \frac{1+\tilde{e}_{cp}-\tilde{p}_{cp}}{2-\alpha} - \frac{\tilde{p}_{cp}-\tilde{w}_{cp}}{2-\alpha} = 0 \tag{27}$$

which yields $\tilde{p}^*_{cp} = \frac{1}{2}\left(1+\tilde{e}_{cp}+\tilde{w}_{cp}\right)$. Comparing the profit function under two regimes the downstream retailer's optimal prices are given by

$$\tilde{p}^*_{cp} = \begin{cases} \frac{1}{2}\left(1+\tilde{e}_{cp}+\tilde{w}_{cp}\right) & \text{if } \tilde{e}_{cp} < 3-2\alpha+\tilde{w}_{cp} \\ \tilde{e}^L_{cp}-1+\alpha & \text{if } \tilde{e}_{cp} \geq 3-2\alpha+\tilde{w}_{cp} \end{cases} \tag{28}$$

In the first stage the upstream content provider has two options: making the downstream adopt accommodation by setting $\left(w_{cp}, e_{cp}\right)$ to satisfy $\tilde{e}_{cp} < 3-2\alpha+\tilde{w}_{cp}$ or implement the limit pricing with the constraint $\tilde{e}^L_{cp} \geq 3-2\alpha+\tilde{w}_{cp}$. Under the accommodation regime the CP maximizes the following profit function: $\underset{p_{cp}}{Max}\, \tilde{\pi}^u_{cp} = \tilde{w}_{cp}\tilde{q}_{cp}\left(\tilde{e}_{cp}\right) - C\left(\tilde{e}_{cp}\right)$. Setting its first derivatives with respect to w_{cp} and e_{cp} to zero gives us the following equilibrium values:

$$\left\{\tilde{p}^*_{cp}, \tilde{e}^*_{cp}, \tilde{q}^*_{cp}, \tilde{w}^*_{cp}\right\} = \left\{\frac{3(2-\alpha)c}{4(2-\alpha)c-1}, \frac{1}{4(2-\alpha)c-1}, \frac{c}{4(2-\alpha)c-1}, \frac{2(2-\alpha)c}{4(2-\alpha)c-1}\right\} \text{ and}$$

$$\left\{\tilde{\pi}^{u*}_{cp}, \tilde{\pi}^{d*}_{cp}\right\} = \left\{\frac{c}{2\left(4(2-\alpha)c-1\right)}, \frac{(2-\alpha)c^2}{\left(4(2-\alpha)c-1\right)^2}\right\} \tag{29}$$

On the other hand, the upstream's choice is to make the downstream implement the limit pricing to maximize the following profit function:

$\underset{p_{cp}}{Max}\, \tilde{\pi}^{uL}_{cp} = \tilde{w}^L_{cp}\tilde{q}^L_{cp} - C\left(\tilde{e}^L_{cp}\right)$ subject to $\tilde{e}^L_{cp} = 3-2\alpha+\tilde{w}^L_{cp}$, which gives us

$$\left\{\tilde{p}^{L*}_{cp}, \tilde{e}^{L*}_{cp}, \tilde{q}^{L*}_{cp}, \tilde{w}^{L*}_{cp}\right\} = \left\{\alpha+\frac{1}{c}-1, \frac{1}{c}, 1, \frac{1}{c}+2\alpha-3\right\} \text{ and } \left\{\tilde{\pi}^{uL*}_{cp}, \tilde{\pi}^{dL*}_{cp}\right\} = \left\{\frac{1}{2c}+2\alpha-3, 2-\alpha\right\} \tag{30}.$$

By comparing profits for each strategy, we conclude that the optimal choice of the upstream is to accommodate piracy if $c > \frac{1}{7-4\alpha} \equiv \tilde{\tilde{c}}_{cp}$ and to limit price if $c \leq \tilde{\tilde{c}}_{cp}$.

Proposition 2 The impact of digital distribution channels on optimal pricing, the demand for legal content and the level of copy protection with comparison to those under the non-digital distribution channels is follows:

1) $e_{cp}^{*} \geq \tilde{e}_{cp}^{*}$

2) $p_{cp}^{*} \leq \tilde{p}_{cp}^{*}$ with $w_{cp}^{*} \leq \tilde{w}_{cp}^{*}$ and $q_{cp}^{*} \geq \tilde{q}_{cp}^{*}$

3) $\overline{c}_{cp} > \tilde{\overline{c}}_{cp}$

The intuition behind proposition 2 can be inferred from the different character of the demand curves for the original content with presence of different types of piracy. The demand curve with non-digital piracy given in equation (4) is depicted in Figure 2 (a) as D_N and is the kinked curve *ABC*. It implies that the higher price of the content, the more consumers will switch to making an illegal copy. Also, the lower price reduces the incentive for consumers to turn to piracy so that the lower portion of the demand curve is the same as the old demand curve, which is denoted as D_O. On the other hand, the demand curve with presence of digital piracy given in equation (25) is depicted in Figure 2 (b) as $\tilde{D}_N$ and is the kinked curve *EFG*. It implies that the lower content price, the harder it is to attract low-valuation consumers to switch from making an illegal copy to purchase the content. It provides less incentive for the monopoly to lower this price to compete against piracy. Also, the higher price enables the monopolist to restore his monopoly power by moving away from the piracy threat so that the higher portion of the demand curve is the same as the old demand curve, which is denoted as $\tilde{D}_O$. Comparing the shape of the two demand curves, the one with digital piracy shows unusual characteristics such as demand being more elastic in the monopoly region at the higher prices than in the piracy region at the lower prices. The opposite characteristics are observed with the other with non-digital piracy. Therefore, if the piracy constraint is binding and the optimal response to that is accommodation, we observe that the price is higher and demand for the original content is lower with digital piracy than with non-digital piracy.

Application of proposition 2 to the music industry requires some cautions, since the level of DRM in the music industry was determined in 1984 with the introduction of music CD before the digitalization and without anticipation of the advent of digital copy. However, a direct

comparison between equation (14) and (28) in the accommodation case yields a higher price under the VDP (I) regime at any given level of DRM. Therefore, this may suggest a possible answer to the counterintuitive empirical observations such as observing non-decreasing prices and decreases in sales in response to digitalization in the music industry in the United States (e.g., Liebowitz, 2006; Peitz and Waelbroeck, 2005). If we assume piracy through digital distribution channels such as P2P networks as horizontally differentiated from the non-digital content, we observe non-decreasing prices and declines in sales as presented in proposition 2.

Similar findings are also observed in post-patent prescription drug market with generic entry, which is so-called "generic competition paradox" by Scherer (1993). One of the most commonly accepted explanations to this paradox lies in the segmentation of the market (Frank and Salkever 1992, 1997, Regan 2008). According to this theory, when the patent of a branded drug expires and a generic entry is expected, the branded firm focuses on its marketing efforts on the remaining brand-royal market segment. By doing so, the branded firm concentrates on the high-valuation customers and raising price.

4. Comparative Statics

We now turn to the effect of a marginal increase in public copy protection, which is comparable to Intellectual Property Right (IPR) protection. As with previous studies in the literature (e.g., Bae and Choi, 2006; Novos and Waldman, 1984), we model the increase in IPR protection as an increase in the cost of piracy faced by the consumers, which makes the piracy a less attractive option. Bae and Choi provide the generalized results of the effects associated with two different types of costs associated with piracy for the monopoly case: constant reproduction cost and proportional degradation rate. Sine the optimal level of private copy protection, which corresponds to the reproduction cost, is endogenously determined by either the content provider or the retailer, we concentrate on the other measure of IPR protection, which is the public copy protection, which is represented by an increase in degradation cost (i.e., a higher α). Proposition 3 and table 2 summarizes the results of the comparative statics.

Proposition 3. Under the accommodation regime, the retail price increases with the strengthening of IPRP. The effects of an increase in IPRP on the authorized usage of the content, however, depend on the types of distribution channels. Under piracy through non-digital

distribution channels higher public protection induces *less* authorized usage whereas it induces *more* authorized usage under piracy through digital distribution channels [see table 2].

A fuller explanation of this result is as follows. The same increase in IPR give rise to different results due to the different changes in the demand for the original content with different types of piracy. If there is an increase in IPRP with non-digital distribution channels, we observe a clockwise *pivot* change above the kink in demand with a "north-west" move in the kink itself that affects the *slope* of the demand curve for legal copies [see Figure 3 (a)]. Due to the proportional increase in the gross copy cost, higher valuation consumers are more adversely affected by an increase in the detection cost. A steeper demand curve means that the elasticity of consumers demand is lower with more market power. Thus, the monopolist is more interested in serving only the high valuation consumers. On the other hand, the same increase in IPR with digital distribution channels, we observe an anticlockwise *pivot* change below the kink in demand with a "north-west" move in the kink itself, which affects the slope of the demand for legal copies [see Figure 3 (b)]. Due to reverse proportional increase in the gross copy cost, lower valuation consumers are more adversely affected by an increase in the detection cost. Facing a flatter demand curve but with increased demand from the low valuation consumers, the optimal response from the monopoly is to increase price but still be able to sell the content to more consumers.

5. Concluding Remarks

Piracy and DRM have drawn substantial attention from academia. Early research on piracy focused on photocopying and addressed the issue of how publishers can recoup some of their lost revenues from copied products (e.g., Liebowitz, 1985). Later research turned to copyright issues and examined how copyright protection affects the level of piracy, pricing, development incentives, and social welfare (e.g., Bae and Choi, 2006; Besen and Raskind, 1991). In the theoretical literature on piracy, the content providers [upstream] and retailers [downstream] were modeled as a single entity. Whereas this assumption may be appropriate for the software industry, it does not capture the characteristics of the music and movie industries where content providers and retailers are different entities. The present paper aims at filling this gap by presenting a detailed analysis of the effect of different ownership structure of copy protection on

the level of price, piracy and copy protection. In order to explain fully the effect of different ownership structure of copy protection this analysis is carried out within a framework where upstream and downstream firms have access to an identical copy protection technology. After ruling out the technological difference in terms of copy protection strategy, we are able to shed some light on the effect of the vertical relationship between the content providers and retailers on the private protection against piracy.

This paper examines how digitalization of contents influences consumer's piracy behavior and firms' optimal choice on the level of copy protection and prices. For this purpose, we constructed a model of vertical relationship incorporating two different types of piracy determined by different distribution channels under the different ownership structure of copy protection. Three different business models are proposed according to the ownership structure of copy protection which determines the right to implement copy protection by vertically-integrated entity, the upstream, and the downstream. In this setup the main findings are as follows; the optimal level of copy protection and prices are determined by different types of ownership structure. The highest level is chosen by vertically integrated firm. The next highest level is the one chosen by the downstream retailer. The lowest is the level chosen by the upstream content provider. Also, the incentive to block piracy is consistent with the order of the level of copy protection. It is shown that the results are dependent upon the ownership structure of copy protection and the degree of opportunistic behavior responding to increasing rival (piracy) costs.

The effect of digitalization on the contents focusing on the music industry has been empirically tested by Peitz and Waelbroeck (2004), Michel (2006), Liebowitz (2006) and Zentner (2006). One of their main findings is the decline in the sales of recorded music. Peitz and Waelbroeck (2005) and Liebowitz (2006) provide a price pattern showing no decline in prices of recorded music, which seems a counterintuitive observation. Many theoretical researchers predict that with the presence of piracy as a possible substitute for the originals, the optimal price of the monopoly should be lower. In order to provide a possible explanation to the price consistency we proposed a model where the non-digital format original and the digital piracy is assumed to be vertically and horizontally differentiated. It is possible that pirated contents are inferior to the original and consumers are substantially differentiated with respect to their attitudes towards the format so that the content providers and off-line retailers react and concentrate on the segment of loyal customers of non-digital format.

To address this issue we analyze the effect of two different types of piracy depending on distribution channels. In doing so, this paper provides new insights to the literature on piracy. We believe introducing horizontally differentiated digital pricy shed light on answering some counterintuitive empirical facts in the previous literature about the impact of digitalization on prices and sales in the case of the music industry. Shift from a non-digital piracy to digital piracy we find non-decreasing prices and decline in sales, which provides the theoretical foundation to justify the claims from the empirical literature.

For policy implication, our theoretical framework show that the effect of piracy depends crucially on the nature of distribution channels (e.g., non-digital versus digital). Strengthening IPR protection results in a price hike, while we have opposite changes in quantities depending on different types of piracy. The results in this paper thus suggest that implementation of IPR protection should pay more attention to distribution specific policy design since the policy change will affect the two types of piracy differently.

Our approach to the effect of digitalization on the content industry with the different ownership structure of private copy protection and piracy through digital distribution channels (e.g., P2P networks) provides significant insight, but there are some limitations, which provide ample opportunity for future research. In our model, we analyze a simplified horizontal differentiation model with presence of digital piracy, but do not explicitly develop a full-fledged model with two different types of downstream retailers in terms of the format of the content (e.g., one with the non-digital content and the other with the digital content) and the control of DRM. Such a model would allow us to analyze an interaction between the retailers with threats of two different types of piracy. This may be a future task of our research.

Table 1 Summary of different regimes according to the different copy protection and piracy

Different Regimes	Ownership of copy protection	Types of retailer	Types of piracy
Vertically differentiated piracy (I)	Content provider	A Brick and mortar store sells non-digital contents	Non-digital
Vertically differentiated piracy (II)	Retailer	An Online retailer sells digital contents	Digital
Vertically and horizontally differentiated piracy	Content provider	A Brick and mortar stores sells non-digital contents	Digital

Table 2 The timing of the game under different regimes

The ownership structure of DRM	**The vertically integrated entity**	**The upstream content provider**	**The downstream retailer**
1st stage	(p_{vi}, e_{vi})	(w_{cp}, e_{cp})	w_r
2nd stage		p_{cp}	(p_r, e_r)

Table 3 Comparative statics under different regimes

regimes	**price**	**quantity**	**copy protection**
Vertically differentiated regime I	$\frac{\partial p_{cp}^*}{\partial \alpha} > 0$	$\frac{\partial q_{cp}^*}{\partial \alpha} < 0$	$\frac{\partial e_{cp}^*}{\partial \alpha} < 0$
Vertically differentiated regime II	$\frac{\partial p_r^*}{\partial \alpha} > 0$	$\frac{\partial q_r^*}{\partial \alpha} < 0$	$\frac{\partial e_r^*}{\partial \alpha} < 0$
Vertically and horizontally differentiated regime	$\frac{\partial \tilde{p}_{cp}^*}{\partial \alpha} > 0$	$\frac{\partial \tilde{q}_{cp}^*}{\partial \alpha} > 0$	$\frac{\partial \tilde{e}_{cp}^*}{\partial \alpha} > 0$

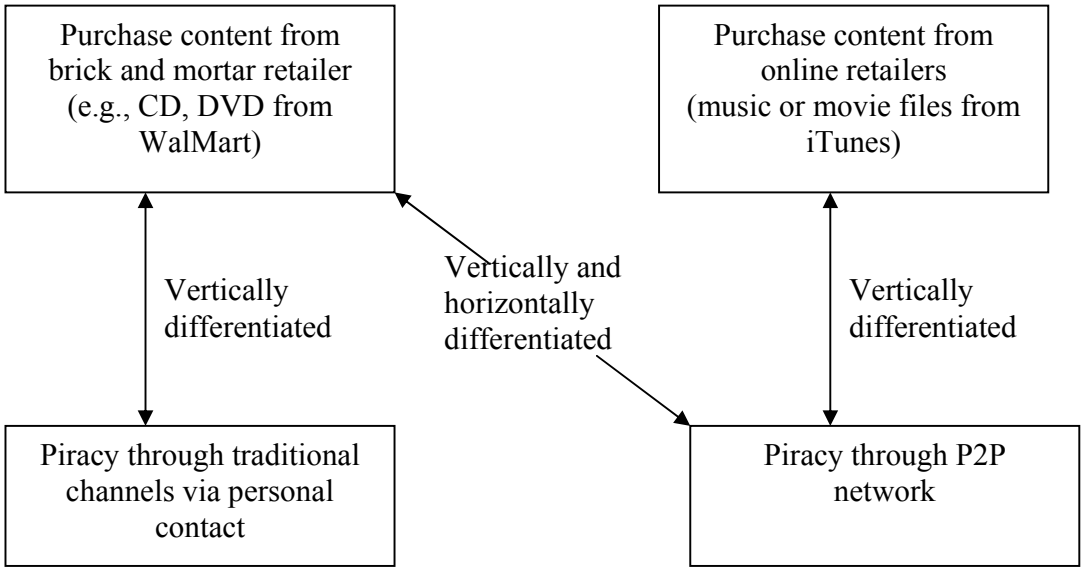
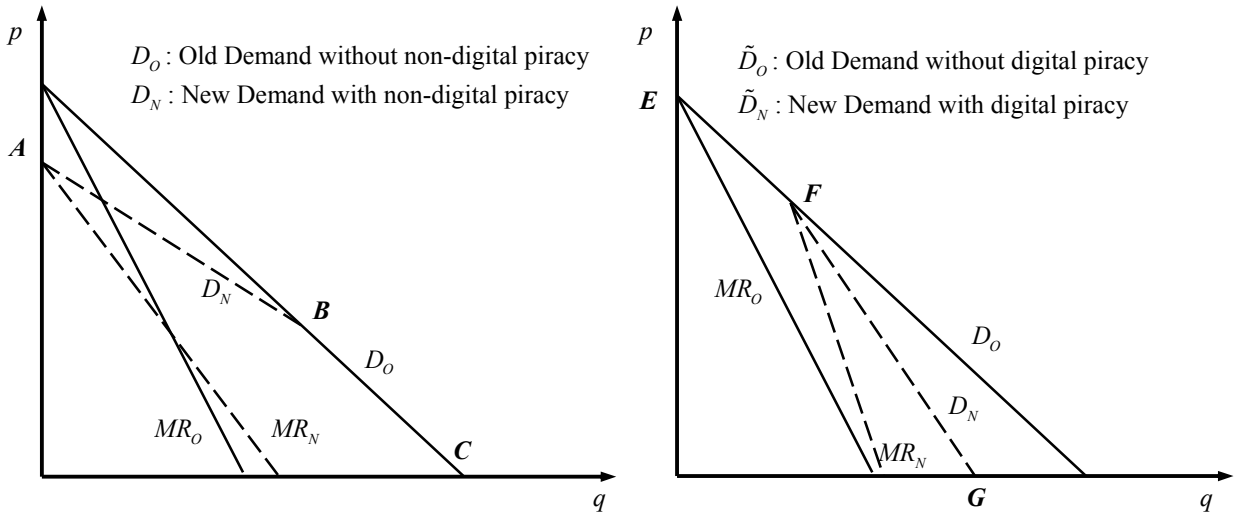


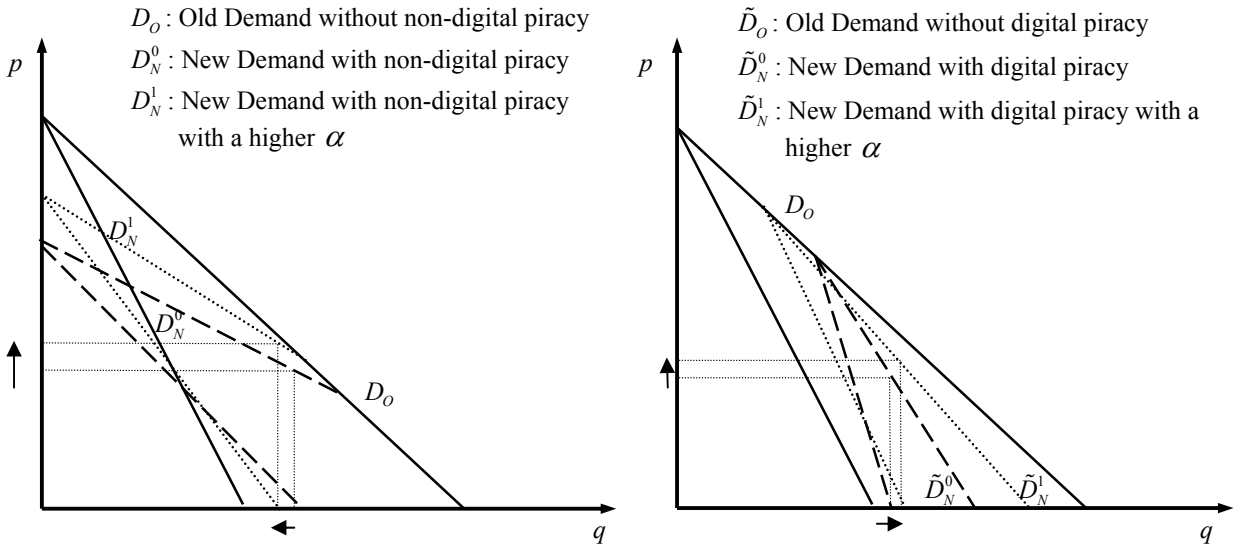
Figure 1 Relationship among content according to format and distribution channels



(a) Demand curve for originals with non-digital piracy

(b) Demand curve for originals with digital piracy

Figure 2 Demand curve for non-digital originals with different types of piracy



(a) Demand curve for originals with non-digital piracy

(b) Demand curve for originals with digital piracy

Figure 3 The Effects of an increase in α

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