Pricing Digital Content with DRM Mechanism

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ABSTRACT
The Internet and file sharing technology (such as P2P network) significantly alleviate the content distribution cost. However, better digital content distribution also means that people can acquire any digital contents easier without purchasing the digital rights. Consequently, digital content providers utilize DRM (Digital Right Management) technology to inhibit the diffusion of pirating.

In this paper, we proposed an analytical model to examine the optimal DRM protection and pricing strategies of digital content. We showed that the structure of the digital content industry (the relationship between content and platform providers) and content quality play important roles in the development of these strategies. DRM protection level decreases as the content provider and platform provider are integrated. As a result, more pirating activities occur. While losing revenue from selling content, the merged company recovers this loss and gains from selling platform at a higher price. Higher content quality will always strengthen the adoption of DRM when content and platform providers are operated independently. However, if both providers are integrated, higher content quality may increase or decline DRM protection level. In addition, we observed that providing content with higher quality will increase (decline) both the sales of legal content and corresponding revenue when content quality is sufficiently high (low).

Categories and Subject Descriptors
I.6.5 [Simulation and Modeling]: Model Development- Modeling Methodologies; J.4 [Computer Applications]: Social and Behavioral Sciences- Economics

General Terms
Measurement, Economics, Human Factors

Keywords
DRM, Digital content, Competition, Integration, Pricing strategy

1. INTRODUCTION
Today, our life is full of various digital products and contents. Even some researches have shown that over 90% of produced information is in digital format [21]. There is no doubt that digital products and contents are already inseparable from our daily life. Since 1979, the invention of Walkman changed our habit revolutionary in using digital contents, and opened the large demand market of digital contents. After 1990, the diffusion of personal computer constructed a general platform and the Internet linked them together. Transmitting digital contents on the Internet (legally) also has lower cost than producing or buying physical discs even though producing scale of discs is already costless for firms. So, the Internet has gradually become the major portal of information in our daily life.

However, the open standards of computer hardware, file formats, and convenient Internet services also mean that pirate is easy. The International Federation of the Phonographic Industry (IFPI) recorded that music sales in the world fell to US$32 billion in 2002, and it means 8% reduction in volume [12]. The Motion Picture Association of America (MPAA), which represents all the major film studios, estimates that between 400,000 and 600,000 films are downloaded every day [5] [18]. The behaviors of digital content consumers hurt the revenue of digital content providers heavily and they all focus on how to have an optimal strategy to ensure their profits.

DRM technology could be viewed as a kind of server side software which is developed by digital content provider to prohibit illegal distribution of digital contents [2]. These rules may include copy protection to legal versions, number of machines or number of times could be used, how long could be used…etc. [3]. Briefly, DRM technology can restrict consumers' illegal behaviors effectively, but it also reduces the flexibility and corresponding value of digital contents. It is an important topic for digital content providers to consider an appropriate DRM protecting level and pricing strategies to avoid illegal pirate behaviors and maximize their profit at the same time.

In this paper, we examine the issues of the pricing strategy and DRM policy of digital content, considering the effects of industry structure and content quality. We consider two situations of industrial organization of digital content. In situation 1, the content playing platform provider and content provider are independent and consumers can not play digital contents without the platform. The platform may be a specific hardware which could not be copied. For example, consumers have to buy a DVD player and a legal DVD disc from different firms to watch a DVD movie. In situation 2, platform manufacturer and content provider

are the merged as one company. For example, consumers buy an iPod from Apple and acquire new contents from Apple's online music store. In the following, we will use several general mathematical functions and coefficients to represent the DRM protection level and digital content providers' pricing strategies. We derive the optimal solutions and propos several interesting propositions which are useful to support the operation of digital content business.

2. LITERATURE REVIEW

There were already several researches about digital right management conducted before. Hunter described the P2P technology's impact on DRM protection [10]. By the proliferation of both Internet access and increase of network bandwidth, digital content consumers not only download digital contents but also have abilities to upload digital contents to do sharing activities. The popularity of Napster, Gnutella [17], Freenet [11], and other P2P platforms changed the way of digital content distribution and establish the position of P2P network for spreading digital contents [1].

But it is undeniable that the Internet and P2P technologies gradually shaped better distribution channels for new digital content products. Gayer and Shy proved that the new distribution channels enhanced the sales of digital content publishers [8]. Shapiro and Varian also discovered that several methods based on the Internet are effective in increasing the profits of digital content providers [19]. In addition, Givon showed that the increase of the number of illegal software copies can increase the demand quantity for legal ones [9].

As information technology advanced, lots of digital content platform are made as a mobile device to strengthen its portable ability such as the example of Apple. Kundur proposed many issues about mobile content delivery. He also provided detail DRM mechanism design examples for digital content distribution and business models. Kundur states that an ideal DRM system should satisfy the balance of information protection, usability, and cost to let all roles in the digital content supply chain would be beneficial [4] [14].

Hunter thought that there are only two ways to solve the problem in DRM: One is peer-to-peer legal question. The digital content providers and P2P software providers should cooperate to make feasible rules in P2P software. The other is how to regulate the use of digital contents after they have been downloaded to the personal computers [10]. And according to Irwin, all major digital content platform manufacturers such as Nokia, Intel, and Vodafone are all devoted in developing more robust and secure OMA (Open Mobile Alliance) DRM solutions that can be used to protect high value digital contents on mobile devices [13]. This indicated the necessary of DRM protection for digital contents and many firms are keeping paying attention to the issue.

In Kwok et al.'s research [16], the DRM technology is implemented on electronic commerce transactions. They use digital water-marking technology as DRM mechanisms for rights insertion, detection, and extraction or integrated it to a Secure Digital Music Initiative (SDMI) system to provide a secure environment for digital music transfer [15]. Torrubia suggested using International cryptography regulations to build security mechanisms for digital right management [20]. Strong encryption has been used in secure transactions of financial data storage or transfer.

Forte express that the DRM protection will extend its adoption to personal creation files in the future [7]. For example, Microsoft's RMS let users to set their personal protection level and it also means that DRM adoption is gradually extended from enterprise to individuals. DRM protection is needed anywhere just digital content exists.

In brief, since the digital technology accelerated the digitalization of all knowledge and contents around us. But the convenience, also the weakness of digital content is its character of easy to copy and transfer. So, many scholars and enterprises are trying to design a DRM mechanism which acquires a balance between digital content providers and consumers. But there are fewer research issues are related to the analysis of market mechanism to enhance DRM kernel design. So, in this paper, we simulate the true situations on the digital content product market and propose several managerial implications based on simple analytical models. Particularly, we focus on the effects of market and content on the DRM protection policy and pricing strategy.

3. THE MODEL

We consider a digital content market which includes a content platform provider, a content provider, and η_0 number of consumers. These consumers can acquire a digital content from purchasing it legally or pirating the content from illegal P2P networks. If a customer chooses to own a legal copy, he/she needs to pay a price, p_c. In addition, all customers have to purchase a playing platform with a price p_h, no matter how he/she get the content. The value function of a digital content, $v(\upsilon,\varepsilon)$ is associated with its content quality υ and the DRM protection level ε conducted on it. It is reasonable to assume $\partial v(\upsilon,\varepsilon)/\partial\upsilon > 0$ and $\partial v(\upsilon,\varepsilon)/\partial\varepsilon > 0$ since all the customers prefer content with higher quality and less protection. The DRM protection level for a pirated content is ε_0 and is assumed to be less than the DRM protection level of original copy (i.e. $\varepsilon_0 < \varepsilon$). Denote pirate diffusion function $\phi(\varepsilon)$ as the probability that a customer can obtain an copy from illegal channels, where $0 \le \phi(\varepsilon) \le 1$. Negative effect of DRM protection on the pirating diffusion indicates $\partial\phi(\varepsilon)/\partial\varepsilon < 0$. The customers are heterogeneous on value discount on the pirated content, which reflects the disutility on the pirating behavior (such as physiological fear to be caught). Individual sensitivity to this disutility is described by θ_i and its value is drawn from uniform distribution function [0, 1]. A customer with higher value of θ_i is less sensitive to the disutility from using pirated content. The utility function of typical user *i* can be formulated as

$$U_i = \begin{cases} v(\upsilon,\varepsilon) - p_c - p_h & \text{he/she purchase the content} \\ \theta_i\phi(\varepsilon)v(\upsilon,\varepsilon_0) - p_h & \text{hr/she pirate the content} \end{cases} \quad (1)$$

Each customer chooses his/her best strategy (purchase or pirate) to maximize the individual utility. Let the consumer with $\hat{\theta}$ is

indifferent in purchasing or pirating the contents. From the individual utility function (1), we get the value of $\hat{\theta}$ by solving $v(\upsilon,\varepsilon) - p_c = \hat{\theta}\phi(\varepsilon)v(\upsilon,\varepsilon_0)$. We have

$$\hat{\theta} = \frac{v(\upsilon,\varepsilon) - p_c}{\phi(\varepsilon)v(\upsilon,\varepsilon_0)} \tag{2}$$

Customers will purchase the content with $\theta_i \le \hat{\theta}$ and pirate the content with $\theta_i > \hat{\theta}$. In addition, the demand function of legal digital content (sales quantity) would be:

$$\eta = \hat{\theta}\eta_0 = \frac{(v(\upsilon,\varepsilon) - p_c)\eta_0}{\phi(\varepsilon)v(\upsilon,\varepsilon_0)} \tag{3}$$

3.1 Market with Independent Content and Platform Providers

We first consider that the platform manufacturer and digital content provider in the digital content industry are independent. We formulate the market game as three-stage game: (1) The platform provider decides the price of the platform p_h. (2) The content provider decides DRM protection level and the price of content. (3) Observe the information provided in previous game stages, all customers decide the way to acquire the content.

Notice that demand function (3) is only associated with the value function and content, pirate diffusion function, and the price of the content. The object function of the digital content provider is:

$$\max_{p_c,\varepsilon} \pi_c = p_c\eta_c = p_c\left(\frac{v(\upsilon,\varepsilon) - p_c}{\phi(\varepsilon)v(\upsilon,\varepsilon_0)}\eta_0\right) \tag{4}$$

The optimal price of digital content can be obtained by solving first order condition $\partial\pi_c / \partial p_c = 0$:

$$p_c^* = \frac{v(\upsilon,\varepsilon)}{2}. \tag{5}$$

Plugging (5) into (4) and solving first order condition $\partial\pi_c / \partial\varepsilon = 0$, the optimal level of DRM protection ε^* is given by solving the following equation:

$$f_1(\upsilon,\varepsilon) = v'(\upsilon,\varepsilon)\phi(\varepsilon) - \frac{1}{2}\phi'(\varepsilon)v(\upsilon,\varepsilon) = 0. \tag{6}$$

Thus, given optimal price p_c^* and DRM protection level ε^*, the quantity of legal content can be written as:

$$\eta^* = \frac{v(\upsilon,\varepsilon^*)\eta_0}{2\phi(\varepsilon^*)v(\upsilon,\varepsilon_0)} \tag{7}$$

Then, according to equation (5) and (7), the profit of the content provider becomes:

$$\pi_c^* = \frac{v^2(\upsilon,\varepsilon^*)\eta_0}{4\phi(\varepsilon^*)v(\upsilon,\varepsilon_0)} \tag{8}$$

Now, we discuss the pricing strategy of the platform provider. Expect the best response pricing function of the content provider $p_c^* = v(\upsilon,\varepsilon)/2$, the objective function of platform provider:

$$\max_{p_h} \pi_h = p_h\eta_0 \ s.t.\ U_i \ge 0, \forall i \tag{9}$$

Therefore, the best response pricing strategy of the platform provider is to set the price of the platform to be $p_h^* = v(\upsilon,\varepsilon^*)/2$. Consequently, we have the profit of the platform provider:

$$\pi_h = \frac{v(\upsilon,\varepsilon^*)\eta_0}{2} \tag{10}$$

3.2 Market with Integrated Content and Platform Providers

In this scenario, the integrated firm decides DRM protection level, and the prices of content and platform simultaneously. The decision of the customers is the same as before. The objective function of the merged firm becomes:

$$\max_{\varepsilon,p_c,p_h} \pi_{c+h} = \left(p_c\left(\frac{v(\upsilon,\varepsilon) - p_c}{\phi(\varepsilon)v(\upsilon,\varepsilon_0)}\right) + p_h\right)\eta_0 \tag{11}$$
$$s.t.\ U_i \ge 0, \forall i$$

After solving first order condition $\partial\pi_{c+h} / \partial p_c = 0$, we can obtain optimal price of the content $p_c^* = v(\upsilon,\varepsilon)/2$ and the optimal price of the platform $p_h = v(\upsilon,\varepsilon)/2$. The profit function of the integrated firm can be rewritten as:

$$\pi_{c+h} = \frac{\eta_0}{2}\left(\frac{v^2(\upsilon,\varepsilon)}{2\phi(\varepsilon)v(\upsilon,\varepsilon_0)} + v(\upsilon,\varepsilon)\right) \tag{12}$$

Analogously, solving first order condition $\partial\pi_{c+h} / \partial\varepsilon = 0$, the optimal DRM protection level ε^* should satisfy the equation:

$$f_2(\upsilon,\varepsilon) = 2v(\upsilon,\varepsilon)v'(\upsilon,\varepsilon)\phi(\varepsilon) - \phi'(\varepsilon)v^2(\upsilon,\varepsilon) + 2\phi^2(\varepsilon)v(\upsilon,\varepsilon_0)v'(\upsilon,\varepsilon) = 0 \tag{13}$$

PROPOSITON 1 (Optimal Pricing and DRM Strategies)
Given value function $v(\upsilon,\varepsilon)$ and pirate diffusion function $\phi(\varepsilon)$,

(i) In both independent and integrated industry structure, the platform provider will set the price of a platform to be $p_h^* = v(\upsilon,\varepsilon^*)/2$ as the content provider set the price of the content p_c^*, where ε^* is the optimal DRM protection level.

(ii) The optimal DRM protection level ε^* can be obtained by:

(a) Solving equation (6) if the industry is operated by independent content and platform providers.

(b) Solving equation (13) if the industry is operated by integrated content and platform providers.

Since $\partial v(\upsilon,\varepsilon)/\partial\varepsilon < 0$, proposition 1 indicates that higher DRM protection has negative impact on the revenue of the platform producer because the platform provider needs to compensate a portion of utility loss due to the DRM mechanism. Condition $\partial v(\upsilon,\varepsilon)/\partial\upsilon > 0$ implies the platform provider benefits if the content provider offers higher quality of content.

3.3 Comparison of Independent and Integrated Digital Content Markets

• ***DRM protection policy***

We first examine the optimal DRM protection policy:

Equation (13) can be rewritten as

$$f_2(\upsilon,\varepsilon) = 2v(\upsilon,\varepsilon)\, f_1(\upsilon,\varepsilon) + 2\phi^2(\varepsilon)v(\upsilon,\varepsilon_0)v'(\upsilon,\varepsilon) = 0 \qquad (14)$$

Let ε_1^* and ε_2^* to be the optimal DRM level used in the market with independent providers and integrated ones respectively. ε_1^* and ε_2^* should satisfy conditions $f_1(\upsilon,\varepsilon_1^*) = 0$ and $f_2(\upsilon,\varepsilon_2^*) = 0$. Since the second term of (14) is negative, we know $f_2(\upsilon,\varepsilon_1^*) < f_1(\upsilon,\varepsilon_1^*) = 0$. Thus, we obtain $\varepsilon_1^* > \varepsilon_2^*$, which implies integration will weaken the adoption of DRM protection level.

• ***Sales of the content***

Next, from (7), we can find there exists a critical value $\hat{\varepsilon}$ such that $\partial\eta/\partial\varepsilon > 0, \forall\varepsilon < \hat{\varepsilon}_\eta$ and $\partial\eta/\partial\varepsilon < 0, \forall\varepsilon > \hat{\varepsilon}_\eta$, $\hat{\varepsilon}_\eta$ is given by solving $\partial\eta/\partial\varepsilon = 0$, or solving equation,

$$g(\upsilon,\varepsilon) = v'(\upsilon,\varepsilon)\phi(\varepsilon) - v(\upsilon,\varepsilon)\phi'(\varepsilon) = 0 \qquad (15)$$

When the DRM protection level is small ($\varepsilon < \hat{\varepsilon}_\eta$), the effect of DRM (anti-pirating) overcomes disutility of infeasibility on using the content. If the DRM protection level is sufficiently high ($\varepsilon > \hat{\varepsilon}_\eta$), the effect of infeasibility is so negative that more people prefer to have a pirated copy of content.

Denote η_1^* as the equilibrium number of legal content in a market with independent content and platform providers and η_2^* the number of legal content in an integrated market. Comparing (6) and (15), we can find $g(\upsilon,\varepsilon) > f_1(\upsilon,\varepsilon)$, which implies that $\varepsilon_2^* < \varepsilon_1^* < \hat{\varepsilon}_\eta$ and $\eta_2^* < \eta_1^*$. Because of less DRM protection, an integrated market results in less sales of the digital content.

• ***Revenues of the content and platform providers***

Because $\partial p_c/\partial\varepsilon = \partial p_h/\partial\varepsilon < 0$, both the prices of the content and platform in integrated market are higher than those in a market with independent ones. Revenue from content sales becomes smaller in an integrated market due to the increasing pirating activities, even though content is sold at a higher price. Nevertheless, the increasing price of platform in integrated market compensates the loss of content to achieve higher profits.

PROPOSITON 2 (Effects of the Market Structure)
When the content and platform providers are integrated:

(i) Both the prices of content and platform will increase.

(ii) DRM protection level will decline.

(iii) Sales and revenue of legal content decline

(iv) The integrated company gains from the extra revenue by selling platform with a high price.

3.4 Impact of Content Quality

Assume the effect of parameter υ (content quality) and ε (DRM protection level) on the valuation of the content is independent. i.e. $\partial^2 v(\upsilon,\varepsilon)/\partial\varepsilon\partial\upsilon = 0$.

In a market with independent content and platform providers, the optimal DRM ε_1^* is given by solving $f_1(\upsilon,\varepsilon) = 0$. The sign of $\partial\varepsilon_1^*/\partial\upsilon$ is the same as the sign $\partial f_1(\upsilon,\varepsilon)/\partial\upsilon$. Because $\partial f_1(\upsilon,\varepsilon)/\partial\upsilon = -\frac{1}{2}\phi'(\varepsilon)\cdot\partial v(\upsilon,\varepsilon)/\partial\upsilon > 0$, we know $\partial\varepsilon_1^*/\partial\upsilon > 0$. Higher content quality results in stronger DRM protection in a market with independent providers.

Similarly, we can analyze the impact of content quality in an integrated market. The optimal DRM protection level is given by solving $f_2(\upsilon,\varepsilon) = 0$. We have

$$\frac{\partial f_2(\upsilon,\varepsilon)}{\partial\upsilon} = 2\cdot\frac{\partial v(\upsilon,\varepsilon)}{\partial\upsilon}\cdot\frac{\partial f_1(\upsilon,\varepsilon)}{\partial\upsilon} + 2\phi^2(\varepsilon)\frac{\partial v(\upsilon,\varepsilon)}{\partial\upsilon}\cdot\frac{\partial v(\upsilon,\varepsilon)}{\partial\varepsilon} \qquad (16)$$

The first term of (16) is positive, but the second term is negative. We know that there exists a quality level $\hat{\upsilon}$ such that $\partial\varepsilon^*/\partial\upsilon > 0, \forall\upsilon > \hat{\upsilon}$ and $\partial\varepsilon^*/\partial\upsilon < 0, \forall\upsilon < \hat{\upsilon}$. $\hat{\upsilon}$ is the solution that satisfies condition $\partial f_2(\upsilon,\varepsilon^*)/\partial\upsilon = 0$. In an integrated market, the impact of content quality may be positive or negative.

PROPOSIITON 3 (Effects of Content Quality)

(i) In a market with independent content and platform providers, increasing content quality results in stronger DRM protection.

(ii) In a market with integrated content and platform providers, increasing content quality results in stronger (weaker) DRM protection when the content is sufficiently low (high).

4. REALIZATION OF FUNCTION FORMULATION: AN EXAMPLE

For the sake of the expositional and analytical convenience, we consider a specific but general formulation:

$$\begin{cases} v(\upsilon,\varepsilon) = \upsilon - \delta\varepsilon^{\alpha} \\ \phi(\varepsilon) = \gamma\varepsilon^{-\beta} \end{cases} \qquad (17)$$

where parameters $\delta,\alpha,\beta,\gamma > 0$

In above function formulation, conditions $\partial v(\upsilon,\varepsilon)/\partial\varepsilon<0$, $\partial\phi(\varepsilon)/\partial\varepsilon<0$, $\partial v(\upsilon,\varepsilon)/\partial\upsilon>0$, and $\partial^2 v(\upsilon,\varepsilon)/\partial\varepsilon\partial\upsilon=0$ are satisfied. Parameter υ is the quality value attached to the content. $\delta\varepsilon^{\alpha}$ is the disutility incurred from DRM protection which is associated with the sensitivity parameters δ and α. Pirate diffusion function $\phi(\varepsilon)=\gamma\varepsilon^{-\beta}$ describes, the probability that a people can acquire the content from pirating. The probability is associated with the network environment γ and the effectiveness of DRM technology β. For the purpose of analytical convenience, and with loss of the generality, we assume $\alpha=\beta=1$.

4.1 Market with Independent Content and Platform Providers

We plug equation (17) into equation (6), and solve it, the solution of ε represents the original DRM protection level:

$$\varepsilon_1^{*}=\frac{\upsilon}{3\delta} \tag{18}$$

Then, according to equation (7), we plug the solution of ε_1^{*} into it to calculate the number of legal digital contents,

$$\eta^{*}=\frac{\upsilon^2\eta_0}{9\gamma\delta(\upsilon-\delta\varepsilon_0)} \tag{19}$$

Next, the p_c^{*} can be achieved by equation (5).

$$p_c=\frac{\upsilon}{3} \tag{20}$$

Now, we have the equations of digital content price p_c^{*} and quantity η^{*}. So, the revenue of digital content provider π_c^{*} is:

$$\pi_c^{*}=\frac{\upsilon^3\eta_0}{27\gamma\delta(\upsilon-\delta\varepsilon_0)} \tag{21}$$

Since the price of the platform is equivalent to p_c^{*}, we have

$$p_h^{*}=\frac{\upsilon}{3} \tag{22}$$

Consequently, the revenue of the platform provider is:

$$\pi_h^{*}=\frac{\upsilon\eta_0}{3} \tag{23}$$

By first order condition to equation (18)-(22), we can acquire:

$$\frac{\partial\varepsilon_1^{*}}{\partial\upsilon}=\frac{1}{3\delta};\ \frac{\partial\eta^{*}}{\partial\upsilon}=\frac{\upsilon(\upsilon-2\delta\varepsilon_0)}{9\gamma\delta(\upsilon-\delta\varepsilon_0)^2};$$

$$\frac{\partial p_c^{*}}{\partial\upsilon}=\frac{1}{3};\ \frac{\partial\pi_c^{*}}{\partial\upsilon}=\frac{\eta_0\upsilon^2(2\upsilon-3\delta\varepsilon_0)}{27\gamma\delta(\upsilon-\delta\varepsilon_0)^2};$$

$$\frac{\partial p_h^{*}}{\partial\upsilon}=\frac{1}{3};\ \frac{\partial\pi_h^{*}}{\partial\upsilon}=\frac{\eta_0}{3}. \tag{24}$$

As we can see, $\frac{\partial\varepsilon_1^{*}}{\partial\upsilon}$ will be more than zero because δ is positive. This means that the DRM protection level increases as product quality increases. In other words, digital content providers use higher DRM protection level to protect valuable products. Equation $\upsilon-2\delta\varepsilon_0$ decides the sign of $\frac{\partial\eta^{*}}{\partial\upsilon}$ would be positive or negative. Positive value indicates that when the content quality increases, number of content sales increases at the same time, vice versa. Similarly, $2\upsilon-3\delta\varepsilon_0$ decides the sign of $\frac{\partial\pi_c^{*}}{\partial\upsilon}$. If $2\upsilon-3\delta\varepsilon_0>0$, the firm would have more revenue when their content has higher quality.

PROPOSITION 4

In a digital content market with independent content and platform providers (given content value function $v(\upsilon,\varepsilon)=\upsilon-\delta\varepsilon$ and pirating diffusion function of $\phi(\varepsilon)=\gamma\varepsilon^{-1}$) : Increasing quality of the digital content υ will

(i) always result in stronger DRM protection, higher price of content, platform, and more revenue of the platform provider.

(ii) increase the sales of content as υ is high ($\upsilon>2\delta\varepsilon_0$), but decrease the sales of content as υ is small. ($\upsilon<2\delta\varepsilon_0$)

(iii) increase the revenue of content as υ is high ($\upsilon>3\delta\varepsilon_0/2$) but decrease the sales of content as υ is low. ($\upsilon<3\delta\varepsilon_0/2$)

It is noteworthy that the revenue of the content provider is positively associated with the sales of the content if content quality is sufficiently low or high ($\upsilon<3\delta\varepsilon_0/2$ *or* $\upsilon>2\delta\varepsilon_0$). If content quality belongs to interval $3\delta\varepsilon_0/2<\upsilon<2\delta\varepsilon_0$, then increasing sales of the content will resulting in the declining of the revenue of the content provider.

4.2 Market with Integrated Content and Platform Providers

Similarly, we plug equation (17) into equation (13) to solve ε. The ε here represents the DRM protection level of contents in the merge firm:

$$\varepsilon_2^{*}=\frac{2\upsilon-\sqrt{\upsilon^2+6\gamma\delta(\upsilon-\delta\varepsilon_0)}}{3\delta} \tag{25}$$

Next, we can obtain the sales of the content:

$$\eta^{*}=\left(\frac{\upsilon^2+\upsilon\sqrt{\upsilon^2+6\gamma\delta(\upsilon-\delta\varepsilon_0)}}{18\gamma\delta(\upsilon-\delta\varepsilon_0)}-\frac{1}{3}\right)\eta_0 \tag{26}$$

The price of the content is set to be:

$$p_c^{*}=\frac{\upsilon+\sqrt{\upsilon^2+6\gamma\delta(\upsilon-\delta\varepsilon_0)}}{6}. \tag{27}$$

The revenue of the content provider is written as:

$$\pi_c^* = \frac{\left(2\upsilon^3 + 2\left(\upsilon^2 - 3\gamma\delta(\upsilon - \varepsilon_0)\right)\sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)}\right)\eta_0}{108\gamma\delta(\upsilon - \delta\varepsilon_0)}. \quad (28)$$

The price of the platform can be achieved as:

$$p_h^* = \frac{\upsilon + \sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)}}{6} \quad (29)$$

The revenue of the platform provider can be obtained as:

$$\pi_h^* = \left(\frac{\upsilon + \sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)}}{6}\right)\eta_0 \quad (30)$$

In order to examine the impact of content quality on the DRM policy, we do the first order condition on ε_2^* with respect to υ:

$$\frac{\partial\varepsilon_2^*}{\partial\upsilon} = \frac{2\sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)} - \upsilon - 3\gamma\delta}{3\delta\sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)}} \quad (31)$$

From (31), we know $\partial\varepsilon_2^*/\partial\upsilon > 0$ if $\upsilon > \hat{\upsilon}$ and $\partial\varepsilon_2^*/\partial\upsilon < 0$ if $\upsilon < \hat{\upsilon}$, where $\hat{\upsilon} = \left(\sqrt{12\gamma^2 + 8\gamma\varepsilon_0} - 3\gamma\right)\delta$

We analyze the impact of content quality on the sales of content:

$$\frac{\partial\eta}{\partial\upsilon} = \frac{\eta_0(\upsilon - 2\delta\varepsilon_0)\left(3\gamma\delta(\upsilon - \delta\varepsilon_0) + \upsilon\left(\upsilon + \sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)}\right)\right)}{18\gamma\delta(\upsilon - \delta\varepsilon_0)^2\sqrt{\upsilon^2 + 6\gamma\delta(\upsilon - \delta\varepsilon_0)}} \quad (32)$$

(32) reveals the fact that $\partial\eta^*/\partial\upsilon > 0$ if $\upsilon > 2\delta\varepsilon_0$ and $\partial\varepsilon_2^*/\partial\upsilon < 0$ if $\upsilon < 2\delta\varepsilon_0$

Finally, we have:

$$\frac{\partial p_c^*}{\partial\upsilon} = \frac{\partial p_h^*}{\partial\upsilon} > 0, \text{ and } \frac{\partial\pi_h^*}{\partial\upsilon} = \frac{\partial p_h^*}{\partial\upsilon}\eta_0 > 0 \quad (33)$$

PROPOSITON 5

With integrated providers (given content value function $v(\upsilon,\varepsilon) = \upsilon - \delta\varepsilon$ and pirating diffusion function of $\phi(\varepsilon) = \gamma\varepsilon^{-1}$) :

Increasing quality of the digital content υ will

(i) always result in higher price of the content, platform, and more revenue of the platform provider.

(ii) strengthen DRM protection as υ is high ($\upsilon > \hat{\upsilon}$), but weaken DRM protection as υ is low ($\upsilon < \hat{\upsilon}$), where $\hat{\upsilon} = \left(\sqrt{12\gamma^2 + 8\gamma\varepsilon_0} - 3\gamma\right)\delta$.

(iii) increase the sales of the content as υ is high ($\upsilon > 2\delta\varepsilon_0$), but increase the sales of the content as υ is low ($\upsilon < 2\delta\varepsilon_0$)

5. CONCLUSION

In this paper, we design two market structure situations to find appropriate DRM protection level and pricing strategy. We used general mathematical functions to represent the providers' and consumers' utility functions. When the digital content provider has DRM protection on their product, we analyze the interesting relationship within price, quantity, and DRM protection level and find some rules that can explain the impact of content quality on the equilibrium results in the two situations.

The results shows that the adoption of DRM technology strengthens as the content and platform are offered by independent units. For example, the famous case of video cassette specification competition: VHS and Beta is appropriate for the situation. SONY hold the Bata cassette producing specification when they corporate with video content providers. At the same time, SONY provides just no or a few digital contents on their digital media platforms and could be realized as an independent platform provider. The rules above showed that NO ONE but SONY can produce Beta cassette and it represented the most powerful DRM rule. Even this is not a successful case, but it is the way for content providers to ensure their stable revenue, especially while digital rights are their main incomes.

Then, If the content provider also offers dedicated platform, the provider tend to use less DRM protection on their content but charge a higher price on the content, which consequently results in the loss of sale of content. However, the firm gains more from the increasing revenue of platform. The most general example is Apple's iPod and iTunes online music store. Although Apple is not the original digital music provider, they provides online music store which collects lots of songs from many traditional music providers. It means that Apple provides both platforms and digital contents at the same time. Actually, in April 2, 2007, Apple announced that they will provide higher quality (256kbps), DRM-free music for all songs from EMI in the online music store in May. The higher quality, DRM-free music is charged $0.3 higher than original ones per song. The real case supports our result because all integrated firms all realized that it is useless to devote precious resource in developing DRM technology. Almost all DRM technology could be cracked and broadcasted through the Internet immediately. So all integrated firms are trying to provide better services and earn revenues from sources rather than digital content itself. In addition, in May 16, 2007, Amazon.com also announced that they will promote online music store this year and provide DRM-free music of EMI online. The recent actions of the two main online music stores show that the time of DRM-free digital contents has been closer and closer.

We further discuss the content quality on the equilibrium strategies, sales, and revenue. If digital contents with higher value (quality) are pirated, it means more loss for digital content providers. So independent content providers adapt higher DRM protection level for high quality contents. For example, movie firms always devoted high level of protection to their newest films but almost nothing to old films; Technology firms usually provide the highest level of protection to their newest and top technology such as the case of SONY. It is all because the new ones represent higher market values for them. One of digital content products' characters is the short life cycle. The newest product is usually promoted with newest technology, high quality, and high market value (or price). So, the higher quality digital contents is worthy for digital content providers to add high level of DRM protection. Some studies also support our result [6]. However, the effect of content quality may be positive or negative. In both market structures, higher quality always results in higher price of the content and platform. The revenue from the platform always benefits from the increasing of content quality. The

impact of content quality on the sales of content is positive when content quality is sufficiently high but is negative if content quality is sufficiently low. The impact of content quality on revenue of content has similar phenomenon. So, the better strategies for digital content providers may be having a cooperation relationship with platform providers just like the EMI's case. We have known that there may be some risks for independent digital content providers because of the unstable revenue results from content quality. Establish the relationship which makes content and platform providers depend each other may be beneficial to both of them.

In this paper, we do not consider the effects about the digital content differentiation. In fact, heterogeneous digital contents and market characters would be the impact factors for both digital content providers and consumers to make decisions. The influence level of heterogeneous products and the situations about monopolistic and duopolistic market would be analyzed deeply in the future research. Including the cost of DRM mechanism and content quality improvement is also a planned direction for future extension.

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