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Abstract

In this paper, we address the issue of illegal copying or counterfeiting of the original product and Intellectual Property Rights (IPR) protections. The original product developer makes costly investment to deter piracy in a given regime of IPR protection. In the presence of a commercial pirate, we find that it is profitable for the original producer to accommodate the pirate when there is weak IPR protection, and deter when the IPR protection is strong. However, in the comparative statics analysis, we find that there is a non-monotonic relationship between the optimal level of deterrence (chosen by the original producer) and the degree of IPR protection in the economy. The relationship between the rate of piracy and IPR protection is found to be monotonically decreasing whereas the relationship between the rate of piracy and the quality of the pirated product turns out to be non-monotonic. On the other side, from the commercial pirate's point of view, the most profitable way to survive in the market is to produce a pirated product of moderate quality. Our model also provided a possible explanation of varying piracy rates across countries/regions.

Keywords: Piracy, Copyright violations, Raising rival's cost, Deterrence, Accommodation, Product quality

JEL Classifications: D23, D43, L13, L86

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1. Introduction

The issue of copyright violations and intellectual property rights (IPR) protection is presently receiving a great deal of attention in various economic analyses. Copyright violations take place when there is piracy or illegal copying or counterfeiting of the original product. These products can be digital products (like software, music CDs, movie DVDs, video games etc.) or non-digital products i.e. regular items (like cloth, shoes, books, bags etc.).[1] In recent years, there is a renewed interest to study the implications of piracy, and mostly those of digital goods piracy because of the rapid advancement of digital copying technology. Conventional copying or counterfeiting of non-digital products (e.g. the fake brands of original goods), was always there in several markets and would continue to be there in future as well. But the growth of digital piracy is now posing an additional threat. Since digital piracy is a relatively new phenomenon compared to the conventional counterfeiting, a lot of recent studies have focused their attention on digital piracy. To study the implications of digital piracy, most of these studies considered a scenario where the pirates are mainly the end-users (see Conner and Rumelt (1991), Takeyama (1994), Shy and Thisse (1999), Chen and Png (2003), Bae and Choi (2006), Belleflame and Picard (2007) among many others).[2] Except few studies (see Slive and Bernhardt (1998), Banerjee (2003), Poddar (2005), Kiema (2008)) the issue of commercial piracy (i.e. piracy for profit) has not been addressed adequately so far in the literature. Even if those few studies addressed commercial piracy, the explicit influence of exogenous IPR protection is never incorporated in the models. In view to that one of the main aims of this paper is to incorporate the impact of IPR protection against copyright violations in an environment of commercial piracy. The framework that is chosen here is a model of entry deterrence. We study strategic aspects related to entry accommodation and entry deterrence equilibrium in a framework where there is one

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[1] Globally counterfeiting activities have risen to 5-7% of world trade, or about $200 billion to $300 billion in lost revenue, according to some estimates for the European Union some years back (see Time Magazine 2001). We believe that the figure has increased significantly in recent years due to the increase in digital piracy.

[2] For a good survey on information (digital) goods end-users piracy, see Peitz and Waelbroeck (2006).

incumbent original producer and a potential commercial pirate[3]. The strategic aspects leading to entry deterrence or entry accommodation under commercial piracy that have been so far studied in the literature, mostly used the "monitoring the pirate policy"; without any explicit reference of the extent of IPR protections that influences the decision of the copyright holder to deter or accommodate a pirate. In this paper we hope to fill in that gap in the literature. In our model of commercial piracy, the strength (degree) of IPR protection and its impact on the economy plays a major role. It is also empirically observed that the degree and the enforcements of IPR protections vary greatly across countries/regions; and most widely between developed and developing countries.[4] As a result, the rate of piracy or counterfeiting activities varies a great deal across countries or regions. We also want to accommodate that fact in our analysis and try to provide an explanation of the phenomenon

We consider a model where there is an original product developer and a commercial pirate (i.e. who sells pirated goods for profits). The original producer can choose to deter or accommodate the pirate. The original producer's decision depends on the degree of the IPR protection that prevails in the economy. Initially, the original product developer makes costly investment to stop or limit piracy. The basic assumption we use here is stopping piracy is a costly activity, but if such costly activity is actively undertaken, it raises the cost of piracy to the pirate.[5] In our framework, the local government/authority *per se* is not monitoring illegal piracy, but there is a general anti-piracy law that exists in the economy, and this is what we define as IPR protections for copyrighted materials.[6] The original product developer takes the level/degree of the IPR

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[3] The model can also be extended to the case where there are many small competitive commercial pirates.

[4] For example, the software piracy rate across countries varies widely; it can be as high as more than 90% in countries like Vietnam, China and can be as low as 25% as in USA. All other countries have piracy rates in between these two extremes. (Source: See BSA and IDC Global Software 2007 for a detailed survey on piracy rates in different countries).

[5] In this regard, our model is similar to the economic analysis of Landes and Posner (1989) in the context of copyright law and to that of Salop and Scheffman (1987) in the context of raising rivals' costs.

[6] As we said earlier, our approach to deter/limit piracy is different from the standard approach of monitoring the pirate by a central authority or the local government and imposing a fine if caught. The monitoring approach is already extensively studied in the literature of digital piracy, in particular, software piracy (see Banerjee (2003, 2006), Lopez-Cunat and Martinez-Sanchez (2007)). Recently, Kiema (2008) in his study on commercial piracy took a different approach and viewed the increased risk of punishment of

protection in the economy as given and then optimally invests to raise the cost of piracy of the pirate. IPR protections can be weak or strong and the original developer adjusts its deterrence level (hence the costly investment) accordingly in an optimal manner.[7]

In this environment, we first characterize completely the entry deterrence and entry accommodation equilibrium. We find that in general, it is profitable for the original producer to accommodate the pirate when there is weak IPR protection, while deterring is profitable when the IPR protection is strong. Next question, we ask whether the level of deterrence set by the original producer and the degree of IPR protection are always substitutes or complements in deterring piracy. To answer this question, in the comparative statics analysis, we find that there is actually a non-monotonic relationship between the optimal level of deterrence (chosen by the product developer) and the degree/strength of IPR protection in the economy. In the case of accommodation, the optimal level of deterrence increases with the degree of IPR protection. In the case of deterrence, we see that when the reliability of the pirated product is not sufficiently high, i.e., when the products are already very differentiated, the original producer will give less effort for deterring entry, thus will reduce deterrence level when IPR protection increases. On the other hand, when the reliability of the pirated product is sufficiently high, i.e. when the products are not too differentiated, the original producer will actually raise the deterrence level till IPR protection increases to a certain level, and then reduce deterrence level when IPR protection increases sufficiently. Thus we observe a non-monotonicity between the level of deterrence and the strength of IPR protection as we move from the case of entry accommodation to entry deterrence. In another finding, we observe that the relationship between the rate of piracy (appropriately defined) and the strength of IPR protection is monotonically decreasing, however, the relationship between the rate of piracy and the quality of the pirated product turns out to be non-monotonic again. Another interesting finding that comes out from our analysis is that, for a profitable piracy, the optimal strategy of the commercial pirate would be to produce a pirated version with moderate reliability. A commercial pirate will not be inclined to produce a

offering a pirate copy to a consumer causes an advertising cost to the commercial pirate whose value is chosen by the government.

[7] For some more studies on IPR protection and entry deterrence see Yao (2005) and Kim (2007).

version which is too low in quality or which is too close to the original product in terms of quality/reliability even if it can produce such varieties.

Our results also provide a theoretical explanation to the varying rates of piracy across countries and regions, a phenomenon observed empirically. There exists empirical studies (see Gopal and Sanders (1998), Husted (2000), Marron and Steel (2000), Holm (2003), Fischer and Rodriguez (2005), Andres (2006)) to explain the varying (software) piracy rates across countries and regions, but to the best of our knowledge no theoretical framework has been developed so far to explain the same phenomenon. In our model, we find that the actual piracy rate depends on three parameters, namely, the consumers' willingness to pay for the product, the quality of the pirated product and the strength of IPR protection that prevails in the economy. It is the interaction of these three parameters that defines the rate of piracy in an economy. In general, we would expect these three parameters to vary across countries/regions, which can very well explain the different piracy rates as well.

Our analysis here encompasses both the digital and non-digital piracy. In that sense, this study can also be considered to be a general study on the implications of copyright violations. The main findings in our comparative statics analysis are empirically testable. For example, it is important to verify whether there indeed exists a non-monotonic relationship between the optimal level of deterrence (i.e. R&D activity chosen by the product developer to deter piracy) and the strength of IPR protection in the economy; or whether we can find a non-monotonic relationship between the perceived quality of the pirated product and the strength of IPR protection.

The plan of the paper is as follows. In the next section, we provide the basic framework. In section 3, we completely analyze the entry accommodation and entry deterrence equilibrium. We do the comparative statics analysis in section 4. In section 5, we briefly analyze another variant of the model to check the robustness of our main findings. Section 6 discusses briefly on the welfare implications; and section 7 concludes.

2. The Model of Commercial Piracy

2.1 The Original Firm and the Pirate

Consider an original firm and a pirate. The pirate has the know-how or the technology to copy/counterfeit the original product. We assume the pirate produces copies, which are of lower quality than the original. The product quality of the pirated good (compared to original) is captured by the parameter q, $q \in (0,1)$. In the case of digital product, although the pirated copies are almost like original, they do not come with any guarantee or supporting services, thus making them inferior compared to the original.

We consider a two-period model, where in the first period $(t=1)$, the original product developer undertakes costly investment in order to deter piracy. It adopts the following entry deterring strategy. It tries to deter the pirate by increasing the cost of copying, in particular, raising the marginal cost of producing a copy of the original. The potential pirate appears in the market of the original product in the second time period $(t=2)$. We assume the higher the entry deterring investment made by the original product developer in the first period, the higher would be the marginal cost of copying by the pirate, hence higher would be the deterrence level. The pirate if survives, competes with the original developer in prices by possibly producing a lower quality, *albeit* a cheaper product. We look for subgame perfect equilibrium of the two-period game and solve the game using the usual method of backward induction.

2.2 Costs and Profits

We assume at $t=1$, the cost of investment of the original product developer to choose the level of deterrence, x, is given by $c_o(x) = x^2/2$. Thus, if the profit of the product developer at $t=2$ is denoted by $\pi_o^2 = p_o D_o$,[8] where p_o is the price charged by the product developer and D_o is the demand it faces, then the net profit of the developer at the end of the game is $\pi_o = \pi_o^2 - c_o(x) = \pi_o^2 - x^2/2$. When the level of deterrence is x, the marginal cost of production for the pirate will be cx, where c is a parameter $(c > 0)$ *exogenously* given (discussion on the interpretation of c follows in the next sub-section).

[8] For simplicity, we assume the marginal cost of production for the original firm is constant and normalized to zero. We also assume no discounting.

If the pirate is in the market at $t = 2$ then its profit function becomes $\pi_p = \left(p_p - cx\right)D_p$, where p_p is the price charged by the pirate and D_p is the pirate's demand.

2.3 Interpretation of *c*

We would like to interpret c in the following way. c is the degree of Intellectual Property Rights (IPR) protection in our model. In other words, c also defines the strength of legal enforcement to stop piracy and it is beyond the control of the original firm (i.e. the copyright holder). It is generally understood that the government or the regulatory authority can influence c. According to a recent study by Andres (2006), the strength of IPR protection mainly consists of two categories: *membership in the international copyright treaties* and *enforcement provisions*.[9]

Note that we have assumed a multiplicative form between c and the level of deterrence x that is chosen by the original firm. The multiplicative form is specifically chosen to figure out the explicit interaction between c and x. In an extreme situation, if $c = 0$, (i.e. zero enforcement by the government) piracy is absolutely costless to the pirate, no matter how much costly investment is undertaken by the original product developer. In this case, the original firm's investment effort has no effect in deterring piracy. On the other hand, a positive c makes the investment effort of the original firm effective. Consequently, a high value of c increases the cost of piracy to the pirate for a given level of entry-deterring investment by the original firm. Thus the multiplicative form implies that it is a joint responsibility of the government and the copyright holder to stop/limit piracy. If one party wants to free ride on the other party to save its own cost, then the net effect to limit piracy is zero.[10]

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[9] Going by the definition and measure of the strength of IPR protections as discussed in Andres (2006), we can generally find a relatively high c in the developed countries where piracy is taken as a serious crime; hence it raises the cost of piracy significantly. On the contrary, in most of the developing countries, we will probably find c to be relatively low, because the enforcement policies against piracy may not be as strict, hence cost of piracy would remain relatively small. In international forums, like WTO, the discussion on the level of c (i.e. the level of IPR protections for a country) is a topic that is often debated among the WTO member and non-member countries.

[10] To see the impact (if there is any) of the functional form on the results, the additive case between c and x is discussed in section 5.

In this study we take *c* as an exogenous parameter, and study what would be the best entry-deterring strategy for the original product developer given an enforcement environment of IPR protection (i.e. given *c*).

2.4 Consumers' Preferences

Consider a continuum of consumers indexed by $X \in [0,\theta]$. X measures a consumer's willingness to pay for the original product. A high value of X means higher valuation for the product and low value of X means lower valuation for the product. Therefore, one consumer differs from another on the basis of his/her valuation for the particular product. Valuations are uniformly with density $1/\theta$ distributed over the interval $[0,\theta]$.[11] Each consumer purchases at most one unit of the good. A consumer's utility function is given as:

$$U = \begin{cases} X - p_o & \text{if buys original product} \\ qX - p_p & \text{if buys pirated product} \\ 0 & \text{if buys none,} \end{cases}$$ [12]

where p_o and p_p are the prices of the original and pirated product respectively.[13]

3. A Complete Characterization of Accommodation and Deterrence Equilibrium

The original producer can accommodate entry or deter entry completely. We start by deriving demands of the product developer and the pirate.

3.1 Deriving Demands of the Product Developer and the Pirate

[11] So the number of consumers is normalized to one.

[12] Note that $q = 0$ will eliminate the pirated product, while $q = 1$ will make the two products identical. In our model $q = 1$ is never possible as we have assumed that the pirated good is of lower quality. Also technically, $q \in (0,1)$ is needed so that demands, prices and profits are not indeterminate.

[13] The utility representation is borrowed from the standard model of vertical product differentiation in the literature (see Shaked and Sutton (1982), Tirole (1988)).

The demand for the original product and for the pirated product, D_o and D_p, can be derived from the distribution of buyers as follows.

[Insert Figure 1]

Recall that consumers are heterogeneous with respect to their values towards the product. Thus, the marginal consumer, $\widehat{X}$, who is indifferent between buying the original product and the pirated version is given by $\widehat{X} - p_o = q\widehat{X} - p_p$, or $\widehat{X} = \left(p_o - p_p\right)/(1-q)$. The marginal consumer, $\widehat{Y}$, who is indifferent between buying the pirated product and not buying any product is given by $q\widehat{Y} - p_p = 0$, or $\widehat{Y} = p_p/q$. Thus, the demand for original product is $D_o = \frac{1}{\theta}\int_{\widehat{X}}^{\theta} dx = \left[(1-q)\theta - \left(p_o - p_p\right)\right]/(1-q)\theta$ and the demand for pirated product is $D_p = \frac{1}{\theta}\int_{\widehat{Y}}^{\widehat{X}} dx = \left(qp_o - p_p\right)/q(1-q)\theta$.

Note that we have implicitly assumed that $qp_o \geq p_p$ when we derive the demand functions as above. When this assumption does not hold true, the demand for pirated product becomes zero while the demand for original producer is $D_o = \left(\theta - p_o\right)/\theta$. Thus, we write the demand functions as the following:

$$D_o = \begin{cases} \left[(1-q)\theta - \left(p_o - p_p\right)\right]/(1-q)\theta & \text{if } qp_o \geq p_p \\ \left(\theta - p_o\right)/\theta & \text{otherwise} \end{cases}, \tag{1}$$

and

$$D_p = \begin{cases} \left(qp_o - p_p\right)/q(1-q)\theta & \text{if } qp_o \geq p_p \\ 0 & \text{otherwise} \end{cases}. \tag{2}$$

3.2 Price Competition in the Product Market

In the second period, if the pirate operates, the two firms engage in a Bertrand price competition and choose the profit maximizing prices of the respective products. Note that the pirate cannot earn positive profit by pricing below marginal cost. So without loss of generality we restrict our attention to $p_p \geq cx$.

The profit function of the pirate is $\pi_p\left(p_p\right)=\left(p_p-cx\right)D_p$ and the profit function of the original firm in period 2 is $\pi_o^2\left(p_o\right)=p_oD_o$. When $cx \leq p_p \leq qp_o$ (which requires $p_o \geq cx/q$), $\pi_p\left(p_p\right)=\left(p_p-cx\right)\left(qp_o-p_p\right)/q(1-q)\theta$. Clearly, $\pi_p\left(p_p\right)$ is strictly concave, $\pi_p'\left(p_p\right)\big|_{p_p=cx}=(qp_o-cx)/q(1-q)\theta \geq 0$ and $\pi_p'\left(p_p\right)\big|_{p_p=qp_o}=-(qp_o-cx)/q(1-q)\theta \leq 0$. So the optimal choice of p_p is defined by $\pi_p'\left(p_p\right)=0$, which gives $p_p\left(p_o\right)=(qp_o+cx)/2$. When $p_o \leq cx/q$, the pirate has no demand since $p_p \geq cx \geq qp_o$. Therefore, the reaction function of the pirate is the following:

$$R_p\left(p_o\right)=\begin{cases}(qp_o+cx)/2 & \text{if } p_o \geq cx/q \\ \text{any price} \geq cx & \text{otherwise}\end{cases}. \tag{3}$$

To derive the reaction function of the original firm, we write $\pi_o^2\left(p_o\right)$ as

$$\pi_o^2\left(p_o\right)=\begin{cases}f\left(p_o\right) & \text{if } 0 \leq p_o \leq p_s \\ g\left(p_o\right) & \text{if } p_o \geq p_s\end{cases},$$

where

$$f\left(p_o\right) \equiv p_o\left(\theta-p_o\right)/\theta, \quad \forall p_o \in R;$$

$$g\left(p_o\right) \equiv p_o\left[(1-q)\theta-\left(p_o-p_p\right)\right]/(1-q)\theta, \quad \forall p_o \in R;$$

$$p_s \equiv p_p/q.$$

It is straightforward to verify that $f\left(p_s\right)=g\left(p_s\right)$ and that both $f\left(p_o\right)$ and $g\left(p_o\right)$ are strictly concave. Next, we examine the signs of $f'(0)$, $f'\left(p_s\right)$ and $g'\left(p_s\right)$. We find that

$$f'(0)>0,\ f'\left(p_s\right)\begin{cases}>0 & \text{if } p_p<q\theta/2 \\ =0 & \text{if } p_p=q\theta/2 \\ <0 & \text{if } p_p>q\theta/2\end{cases}, \text{ and } g'\left(p_s\right)\begin{cases}>0 & \text{if } p_p<q(1-q)\theta/(2-q) \\ =0 & \text{if } p_p=q(1-q)\theta/(2-q) \\ <0 & \text{if } p_p>q(1-q)\theta/(2-q)\end{cases}.$$ Note

that $q(1-q)\theta/(2-q)<q\theta/2$.

Then, (1) when $p_p \le q(1-q)\theta/(2-q)$, since $f(p_o)$ and $g(p_o)$ are strictly concave, $f'(p_s) > 0$ and $g'(p_s) \ge 0$, [14] the optimal choice of p_o is defined by $g'(p_o) = 0$, which gives $p_o(p_p) = (p_p + (1-q)\theta)/2$; (2) when $q(1-q)\theta/(2-q) \le p_p \le q\theta/2$, since $f(p_o)$ and $g(p_o)$ are strictly concave, $f'(p_s) \ge 0$ [15] and $g'(p_s) \le 0$, the optimal choice of p_o is $p_o(p_p) = p_s = p_p/q$; (3) when $p_p \ge q\theta/2$, since $f(p_o)$ and $g(p_o)$ are strictly concave, $f'(p_s) \le 0$ and $g'(p_s) < 0$, [16] the optimal choice of p_o is defined by $f'(p_o) = 0$, which gives $p_o(p_p) = \theta/2$. Therefore, the reaction function of the original producer can be summarized as

$$R_o(p_p) = \begin{cases} (p_p + (1-q)\theta)/2 & \text{if } p_p \le q(1-q)\theta/(2-q), \\ p_p/q & \text{if } q(1-q)\theta/(2-q) \le p_p \le q\theta/2, \\ \theta/2 & \text{if } p_p \ge q\theta/2. \end{cases} \tag{4}$$

Note that if the price of the pirated product is high enough (i.e., $p_p \ge q\theta/2$), the original producer's best response is to set monopoly price $p_o = \theta/2$; if the price of the pirated product is sufficiently low (i.e., $p_p \le q(1-q)\theta/(2-q)$), the original producer's best response is to share the demand with the pirate; while it sets price $p_o = p_p/q$ such that there is no demand for the pirated product if the price of the pirated product is intermediate.

Figure 2 plots the reaction functions for three cases: $x \le q(1-q)\theta/c(2-q)$, $q(1-q)\theta/c(2-q) \le x \le q\theta/2c$ and $x \ge q\theta/2c$. But the pirate's best response to p_o when $p_o < cx/q$ is omitted in the figure since the best response is any price no less than *cx*. In the first two cases, this does not have any effect on our analysis since the part of the

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[14] Since $f(p_o)$ is strictly concave and $f'(p_s) > 0$, $f(p_o)$ is strictly increasing in the region $[0, p_s]$.

[15] See the previous footnote.

[16] Since $g(p_o)$ is strictly concave and $g'(p_s) < 0$, $g(p_o)$ is strictly decreasing in the region $[p_s, +\infty)$.

pirate's best response curve does not intersect the original producer's best response curve. In the third case, it is clear that the equilibrium involves $p_o = \theta/2$ and p_p=any price $\geq cx$.

[Insert Figure 2]

We thus distinguish three cases: $x \leq q(1-q)\theta/c(2-q)$, called *accommodating strategy* of the original producer, $q(1-q)\theta/c(2-q) \leq x \leq q\theta/2c$, called *deterrence strategy*, and $x \geq q\theta/2c$, called *blockade strategy*.

When $x \leq q(1-q)\theta/c(2-q)$, the equilibrium prices are determined by $R_o(p_p) = (p_p + (1-q)\theta)/2$ and $R_p(p_o) = (qp_o + cx)/2$. It is then straightforward to obtain equilibrium prices

$$p_o = \left[2(1-q)\theta + cx\right]/(4-q),\ p_p = \left[q(1-q)\theta + 2cx\right]/(4-q). \tag{5}$$

The demand for the original product is given by $D_o = \left[2(1-q)\theta + cx\right]/(4-q)(1-q)\theta$, and the profit in the second stage is

$$\pi_o^2(x) = \left[2(1-q)\theta + cx\right]^2/(4-q)^2(1-q)\theta; \tag{6}$$

When $q(1-q)\theta/c(2-q) \leq x \leq q\theta/2c$, the equilibrium prices are determined by $R_o(p_p) = p_p/q$ and $R_p(p_o) = (qp_o + cx)/2$. The equilibrium prices are then

$$p_o = cx/q,\ p_p = cx. \tag{7}$$

The demand for the original product is given by $D_o = (q\theta - cx)/q\theta$, and the profit in the second stage is

$$\pi_o^2(x) = cx(q\theta - cx)/q^2\theta; \tag{8}$$

When $x \geq q\theta/2c$, the original producer charges the monopoly price $p_o = \theta/2$.The demand for the original product is $D_o = 1/2$, and the profit in the second stage is

$$\pi_o^2(x) = \theta/4.\text{[17]} \tag{9}$$

[17] Note that in each case we do not write the pirate's demand and profit explicitly since only the product developer moves in the first stage.

3.3 Choice of Optimal Level of Deterrence by the Original Firm

Now we move on to the first period of the game. In this period, the original firm decides on its optimal choice of the level of x to deter piracy. Thus it maximizes its net profit $\pi_o = \pi_o^2 - c_o(x) = \pi_o^2 - x^2/2$ with respect to x. We are going to derive the original firm's choice of optimal level of deterrence.

As a first step, we notice that $x > q\theta/2c$ is strictly dominated by $x = q\theta/2c$. Since the expression of (8) is equal to $\theta/4$ when evaluated at $x = q\theta/2c$, which means regarding $x = q\theta/2c$ as a deterrence strategy or a blockade strategy makes no difference, we can ignore the blockade strategy when looking for the optimal level of deterrence.

Next, we write the original firm's profit function as

$$\pi_o(x) = \begin{cases} h(x) & \text{if } x \le x_s \\ l(x) & \text{if } x_s \le x \le q\theta/2c \end{cases},$$

where

$$h(x) \equiv \left[2(1-q)\theta + cx\right]^2 \big/ (4-q)^2 (1-q)\theta - x^2/2, \quad \forall x \in R;$$

$$l(x) \equiv cx(q\theta - cx)/q^2\theta - x^2/2, \quad \forall x \in R;$$

$$x_s \equiv q(1-q)\theta/c(2-q).$$

It is straightforward to verify that $h(x_s) = l(x_s)$ and that $l(x)$ is strictly concave. Moreover, $h''(x) \begin{cases} < 0 & \text{if } c^2 < \alpha(q,\theta) \\ = 0 & \text{if } c^2 = \alpha(q,\theta) \\ > 0 & \text{if } c^2 > \alpha(q,\theta) \end{cases}$, which means that $h(x)$ is strictly concave when $c^2 < \alpha(q,\theta)$ while it is strictly convex when $c^2 > \alpha(q,\theta)$, where $\alpha(q,\theta) = (4-q)^2(1-q)\theta/2$. Next, we examine the signs of $h'(0)$, $h'(x_s)$, $l'(x_s)$ and $l'(q\theta/2c)$. We find that

$$h'(0) > 0, \quad h'(x_s) \begin{cases} < 0 & \text{if } c^2 < \beta(q,\theta) \\ = 0 & \text{if } c^2 = \beta(q,\theta) \\ > 0 & \text{if } c^2 > \beta(q,\theta) \end{cases}, \text{ and } l'(x_s) \begin{cases} < 0 & \text{if } c^2 < \gamma(q,\theta) \\ = 0 & \text{if } c^2 = \gamma(q,\theta) \\ > 0 & \text{if } c^2 > \gamma(q,\theta) \end{cases}, \quad l'(q\theta/2c) < 0,$$

where $\beta(q,\theta) = q(4-q)(1-q)\theta/2$ and $\gamma(q,\theta) = q(1-q)\theta$. Note that

$\gamma(q,\theta)<\beta(q,\theta)<\alpha(q,\theta)$. Also, note that "$h'(0)>0$" means that the optimal level of deterrence must be strictly positive and that "$l'(q\theta/2c)<0$" means that the optimal level of deterrence must not be so high that the pirate is blockaded.

Then, (1) when $c^2<\gamma(q,\theta)$, since both $h(x)$ and $l(x)$ are strictly concave, $h'(x_s)<0$ and $l'(x_s)<0$,[18] the optimal choice of x is defined by $h'(x)=0$, which gives $x^*=x_h=4c(1-q)\theta\Big/\left[(4-q)^2(1-q)\theta-2c^2\right]$; (2) when $c^2>\alpha(q,\theta)$, since $h(x)$ is strictly convex, $l(x)$ is strictly concave, $h'(x_s)>0$, $l'(x_s)>0$,[19] the optimal choice of x is defined by $l'(x)=0$, which gives $x^*=x_l=cq\theta\Big/\left(q^2\theta+2c^2\right)$; (3) when $\beta(q,\theta)<c^2<\alpha(q,\theta)$, since both $h(x)$ and $l(x)$ are strictly concave, $h'(x_s)>0$, $l'(x_s)>0$,[20] the optimal choice of x is also defined by $l'(x)=0$, which gives $x^*=x_l=cq\theta\Big/\left(q^2\theta+2c^2\right)$; (4) when $\gamma(q,\theta)<c^2<\beta(q,\theta)$, since both $h(x)$ and $l(x)$ are strictly concave, $h'(x_s)<0$, $l'(x_s)>0$, $\pi_o(x)$ is double-peaked; as a result, we must compare $h(x_h)$ and $l(x_l)$. It is straightforward to obtain $h(x_h)=4(1-q)^2\theta^2\Big/\left[(4-q)^2(1-q)\theta-2c^2\right]$ and $l(x_l)=c^2\theta\Big/2\left(q^2\theta+2c^2\right)$.

Since $h(x_h)-l(x_l)=\dfrac{\theta\left[2c^4-q(1-q)(8+q)\theta c^2+8q^2(1-q)^2\theta^2\right]}{2\left[(4-q)^2(1-q)\theta-2c^2\right]\left(q^2\theta+2c^2\right)}\begin{cases}\geq 0 & if\ c^2\leq\phi(q,\theta)\\ \leq 0 & if\ c^2\geq\phi(q,\theta)\end{cases}$,

where $\phi(q,\theta)=q(1-q)\left(8+q-\sqrt{q(16+q)}\right)\theta\Big/4$, the original firm's optimal choice is $x^*=x_h$ when $\gamma(q,\theta)<c^2<\phi(q,\theta)$ and is $x^*=x_l$ when $\phi(q,\theta)<c^2<\beta(q,\theta)$.

[18] Since $l(x)$ is strictly concave and $l'(x_s)<0$, $l(x)$ is strictly decreasing in the region $[x_s,+\infty)$. Also recall $h'(0)>0$.

[19] Since $h(x)$ is strictly convex, $h'(0)>0$ and $h'(x_s)>0$, $h(x)$ is strictly increasing in the region $[0,x_s]$. Since we have commented $h'(0)>0$ before, we do not mention it again in the text.

[20] Since $h(x)$ is strictly concave and $h'(x_s)>0$, $h(x)$ is strictly increasing in the region $[0,x_s]$.

In the following proposition, we summarize the results and completely characterize the entry accommodation equilibrium and entry deterrence equilibrium in the whole parameter space of c, q and θ.

Proposition 1

(i) *When $c^2 \le \phi(q,\theta)$, the original producer's optimal level of deterrence is $x^* = x_h = 4c(1-q)\theta \Big/ \left[(4-q)^2(1-q)\theta - 2c^2\right]$. In this case, it accommodates the pirate and shares the market with the pirate.*

(ii) *When $c^2 \ge \phi(q,\theta)$, the original producer's optimal level of deterrence is $x^* = x_l = cq\theta \Big/ \left(q^2\theta + 2c^2\right)$. In this case, it deters the pirate and the pirate has no demand.*

Summary: The point is if the innovator plays a deterrence strategy when *c* is low, then it may not be optimal to the innovator, an accommodating strategy would be more appropriate in this case. Similarly when *c* is high, accommodating strategy is not optimal but the deterrence strategy is.

4. Comparative Statics

4.1 The relationship between the optimal level of deterrence (*x*) and the degree of IPR protection (*c*)

When $c^2 \le \phi(q,\theta)$, i.e. when the original firm always accommodates the pirate, we have

$$\partial x^* / \partial c = 4(1-q)\theta\left[(4-q)^2(1-q)\theta + 2c^2\right] \Big/ \left[(4-q)^2(1-q)\theta - 2c^2\right]^2 > 0 .$$

We note that the relationship between the level of deterrence *x* and IPR protection *c* is complementary.

At the first instance it may seem surprising that the original producer chooses a higher x when the degree of IPR protection c increases since the intuition would suggest that the original producer should reduce x (in order to save cost) when c increases since a higher c anyway implies a higher cost of piracy. However, under accommodation, one should not overlook the other effect of increasing the deterrence level and that is, to increase the cost of piracy to the pirate, which makes the pirate less competitive as well. The latter effect, which we call strategic effect, turns out to be more beneficial than cost saving to the original producer, when it accommodates entry.

When $c^2 \geq \phi(q,\theta)$, i.e. when the original firm deters the pirate, we have

$$\partial x^*/\partial c = \partial\left(cq\theta/\left(q^2\theta+2c^2\right)\right)/\partial c = q\theta\left(q^2\theta-2c^2\right)/\left(q^2\theta+2c^2\right)^2 \begin{cases} >0 \text{ if } c^2 < q^2\theta/2 \\ =0 \text{ if } c^2 = q^2\theta/2 \\ <0 \text{ if } c^2 > q^2\theta/2 \end{cases}.$$

We first compare $\phi(q,\theta)$ and $q^2\theta/2$. Computations yield $\phi(q,\theta) > q^2\theta/2$ when $q < 0.7239$; and $\phi(q,\theta) < q^2\theta/2$ when $q > 0.7239$. Thus we have the following result under deterrence.

Lemma 1 *When $c^2 \geq \phi(q,\theta)$, i.e. when the original firm deters the pirate,*

(i) *if $q < 0.7239$, $\partial x^*/\partial c < 0$; however,*

(ii) *if $q > 0.7239$, $\partial x^*/\partial c > 0$ as long as $\phi(q,\theta) < c^2 < q^2\theta/2$, and $\partial x^*/\partial c < 0$ when $c^2 > q^2\theta/2$. Thus, in this range of q the relationship between optimal level of deterrence and the degree of IPR protection is non-monotonic.*

Once the original producer decides to deter the entry, when we see that the reliability of the pirated product is not sufficiently high, i.e., when the products are already very differentiated, the original producer will give less effort for deterring entry, thus will reduce x when c increases. On the other hand, when the reliability of the pirated product is sufficiently high, i.e. when the products are not too differentiated, the original producer will raise x before c increases to $q\sqrt{\theta/2}$ and then reduce x when

c increases further. Thus x and c can be either substitutes or complements, depending on the actual parametric configuration.

Thus, combining the entry accommodation and entry deterrence together we find the following.

Proposition 2

There is a non-monotonic relationship between the level of deterrence and the strength of IPR protection as we move from accommodation to deterrence equilibrium.

Figures 3 and 4 illustrate the overall relationship between the level of deterrence and the strength of IPR protection when $q = 0.5$ and $q = 0.9$ respectively; and we set $\theta = 1$ in each figure.

[Insert Figures 3 and 4]

We believe this is an important result to verify empirically. In the empirical literature there are results on the relationship between software copyright protection and national piracy rates across *countries* (see Andres 2006 among others), but there are no such studies done at the *firm* level. The above result, which can be interpreted as the relationship between the copyright holder firm's R&D expenditure to deter piracy and the strength of the copyright protection law, forms a suitable hypothesis for empirical testing.

4.2 Rate of Piracy

We define the ratio of $D_p \big/ \left(D_o + D_p\right)$ to measure the rate of piracy. Thus the higher the ratio, the higher will be the rate of piracy.

When $c^2 \le \phi\left(q, \theta\right)$, i.e. when the original firm accommodates the pirate, we know $x^* = 4c\left(1-q\right)\theta \Big/ \left[\left(4-q\right)^2\left(1-q\right)\theta - 2c^2\right]$. In this case, it is straightforward to obtain $D_o = 2\left(1-q\right)\left(4-q\right)\theta \Big/ \left[\left(4-q\right)^2\left(1-q\right)\theta - 2c^2\right]$, $D_p = \left[q\left(1-q\right)\left(4-q\right)\theta - 2c^2\right] \Big/ q\left[\left(4-q\right)^2\left(1-q\right)\theta - 2c^2\right]$

and the ratio is thus $D_p/(D_o+D_p)=[q(1-q)(4-q)\theta-2c^2]/[3q(1-q)(4-q)\theta-2c^2]$, which is clearly decreasing in c.

When $c^2 \geq \phi(q,\theta)$, entry is deterred and the rate of piracy is zero.

Proposition 3

When there is piracy, the rate of piracy is always decreasing in c .

This result just follows from our intuition that increasing the strength of IPR protection unambiguously reduces the rate of piracy.[21]

4.3 Rate of Piracy and Quality of the Pirated Product (*q*)

When $c^2 \leq \phi(q,\theta)$,

$$\partial\left(D_p/(D_o+D_p)\right)/\partial q = 3(3q^2-10q+4)c^2\theta/\left[3q(1-q)(4-q)\theta-2c^2\right]^2 \begin{cases} >0 \text{ when } q<0.465 \\ <0 \text{ when } q>0.465 \end{cases}.$$

We thus have the following finding.

Proposition 4

When $q<0.465$ *(i.e. when q is small), the rate of piracy is increasing in* q*, while it is decreasing in* q *when* $q>0.465$ *(i.e. when q is large). Thus, the relationship between the rate of piracy and the quality of the pirated product is non-monotonic when there is piracy.*

The intuition for above result is as follows. When a consumer chooses between a pirated copy and original copy, she cares about both the reliability/quality and the price difference. When a pirated product becomes more and more reliable, the price competition between the pirate and the original producer becomes more and more intense, the price difference becomes smaller and smaller. This eventually leads to a non-

[21] Recent empirical study by Andres (2006) also confirms this result.

monotonic relationship. When q is small, the price difference effect dominates; whereas when q is large, the reliability/quality effect dominates. Our interesting finding here is against the so-called conventional wisdom. Conventional wisdom would suggest that reliable pirated products means higher demand of the pirated good. However, in that logic the price difference effect is ignored. As products get less differentiated, lower will be the price difference between the pirated and original product. In such situations people will tend to buy the original product even if they have to pay little extra. We believe this result should also be empirically testable.

4.4 The Optimal Reliability of the Pirated Product

In the light of the above result, from the commercial pirate's point of view, producing a pirated product with moderate reliability is more desirable than one with high reliability.

In this subsection, we are going to illustrate this point more formally. We want to endogenize the pirate's choice of *q*. It is somewhat a deviation from the model in section 2, where *q* is exogenous. Specifically, we now consider a three-period game by inserting one period in between the two periods in the original two-period model. In the new-added period, the pirate chooses the reliability of the pirated product.

First note that only when $c^2 \le \phi(q,\theta)$ the pirate is accommodated. Clearly, $\phi(q,\theta)$ is close to 0 when *q* is either sufficiently close to 0 or sufficiently close to 1. It is straightforward to verify that $\phi(q,\theta)$ is strictly concave and obtains the maximum (0.3545θ) at $q = 0.4547$. So for a given *c*, the pirate is accommodated only when *q* is intermediate. For example, when $c^2 = 0.3\theta$, the pirate is accommodated only when *q* is in the regime $[0.2627, 0.6596]$.

Next, we will find the optimal choice of *q*. When the pirate is accommodated, the equilibrium prices are given by Eq.(5), and the pirate's profit is $\pi_p =$ $\left(\frac{1}{4-q}\left(q(1-q)\theta+2cx\right)-cx\right)\left(q\frac{1}{4-q}\left(2(1-q)\theta+cx\right)-\frac{1}{4-q}\left(q(1-q)\theta+2cx\right)\right)=\frac{\left(q(1-q)\theta-(2-q)cx\right)^2}{q(1-q)(4-q)^2\theta}$.

The optimal choice of *q* is then determined by $\partial\pi_p/\partial q = 0$. Straightforward computation yields $sign\left(\partial\pi_p/\partial q\right)=sign\left(q^3\left(7\theta-2cx\right)-q^2\left(11\theta-9cx\right)+2q\left(2\theta-9cx\right)+8cx\right)$. So the optimal choice of *q* is the solution to the following equation:

$$q^3\left(7\theta-2cx\right)-q^2\left(11\theta-9cx\right)+2q\left(2\theta-9cx\right)+8cx=0\,. \tag{10}$$

Clearly, when evaluated at *q*=0, $\partial\pi_p/\partial q>0$, while when evaluated at *q*=1, $\partial\pi_p/\partial q<0$. This also shows that the optimal choice of *q* is intermediate. For example, when $\theta=1$ and *cx*=0.1, the solution to Eq. (10) is *q*=0.582.

Hence, we conclude the following:

Proposition 5

For a profitable piracy, the optimal strategy of the commercial pirate would be to produce a pirated version with moderate reliability.

This implies, in general, a commercial pirate will not be inclined to produce a version which is too low in quality or which is too close to the original product in terms of quality/reliability even if it has the means to do so.

5. Additive Case of *c* and *x*

Here we briefly analyze the case of additive form of the cost of piracy. Again, there are three different strategies for the original producer: accommodation strategy, $x\le q(1-q)\theta/(2-q)-c$; deterrence strategy, $q(1-q)\theta/(2-q)-c\le x\le q\theta/2-c$; and blockade strategy, $x\ge q\theta/2-c$. But the blockade strategy can be ignored since it is never optimal for the original producer.

5.1 Accommodation or Deterrence?

We completely characterize the entry accommodation equilibrium and entry deterrence equilibrium in the whole parameter space of c,q and θ. Following the same procedure as in Section 3.3, we can obtain the results stated in Proposition 1A.[22]

[22] The detailed analysis is available from authors upon request.

Define

$$\eta(q,\theta)=\frac{q(1-q)(16-12q+q^2)\theta+6q-8-q\sqrt{(1-q)(2+q^2\theta)\left((4-q)^2(1-q)\theta-2\right)}}{2(2-q)(8-8q+q^2)}.$$

Proposition 1A

(i) *When* $q(4-q)(1-q)\theta\le 2$ *, the original producer's optimal level of deterrence is* $x^*=(-2c+q\theta)/(q^2\theta+2)$ *. In this case, it deters the pirate and the pirate has no demand.*

(ii) *When* $q(4-q)(1-q)\theta>2$,

(iia) When $c\le\eta(q,\theta)$*, the original producer's optimal level of deterrence is* $x^*=2\left(c+2(1-q)\theta\right)/\left((4-q)^2(1-q)\theta-2\right)$*. In this case, it accommodates the pirate and shares the market with the pirate.*

(iib) When $\eta(q,\theta)\le c<q\theta/2$ *, the original producer's optimal level of deterrence is* $x^*=(-2c+q\theta)/(q^2\theta+2)$ *. In this case, it deters the pirate and the pirate has no demand. When* $c\ge q\theta/2$*, there is no need to deter the pirate strategically. Piracy is blockaded anyway due to exogenous high level of IPR protection.*

In Proposition 1A(i), the condition $q(4-q)(1-q)\theta\le 2$ can be interpreted as the consumer taste not sufficiently diversified. In such a case, the original producer necessarily deters the pirate. On the contrary, when the consumer taste is sufficiently diversified, the original producer deters the pirate only if the degree of intellectual property right is high, since the deterrence is too costly if the degree of intellectual property right is low. Furthermore, if the degree of intellectual property right is sufficiently high, deterrence is blockaded.

5.2 The relationship between the optimal level of deterrence (*x*) and the degree of IPR protection (*c*)

When $c \le \eta(q,\theta)$ and $q(4-q)(1-q)\theta > 2$, i.e., when the original firm always accommodates the pirate, clearly we have $\partial x^*/\partial c > 0$. The relationship between *x* and *c* is always complementary.

On the contrary, when $\eta(q,\theta) \le c < q\theta/2$ and $q(4-q)(1-q)\theta > 2$, or when $q(4-q)(1-q)\theta \le 2$, i.e. when the original firm deters the pirate, clearly, we have $\partial x^*/\partial c < 0$. Now unlike the multiplicative case, here under deterrence *x* and *c are always* substitutes. We find no non-monotonicity.

However, overall, when $q(4-q)(1-q)\theta > 2$, there is still non-monotonicity between *x* and *c*. Thus we summarize:

Proposition 2A

When the consumer taste is sufficiently diversified, i.e., when $\theta > 2/q(4-q)(1-q)$, *there is a non-monotonic relationship between the level of deterrence and the strength of IPR protection as we move from accommodation to deterrence equilibrium. On the contrary, when* $\theta \le 2/q(4-q)(1-q)$ *, the relationship is monotonic: the higher the degree of IPR protection, the lower the level of deterrence.*

5.3 Rate of Piracy

As before, we define the ratio of $D_p/(D_o + D_p)$ to measure the rate of piracy.

When $c \le \eta(q,\theta)$ and $q(4-q)(1-q)\theta > 2$, i.e. when the original firm accommodates the pirate, it can be shown that $\frac{D_p}{D_o + D_p} = \frac{q(1-q)(4-q)\theta - (2-q)(4-q)c - 2}{3q(1-q)(4-q)\theta - 2(1-q)(4-q)c - 2}$ is decreasing in c.

In all the other cases, entry is either deterred or blockaded; thus, the rate of piracy is zero.

Proposition 3A

When there is piracy, the rate of piracy is always decreasing in c.

5.4 Rate of Piracy and Quality of the Pirated Product (*q*)

When $c \le \eta(q,\theta)$ and $q(4-q)(1-q)\theta > 2$, simple computation yields

$$\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) = \frac{2(4-q)^2 c^2 + \left((4-q)^2\left(4-8q+q^2\right)\theta + 8 - 4q\right)c + 4\left(4-10q+3q^2\right)\theta}{\left(3q(1-q)(4-q)\theta - 2(1-q)(4-q)c - 2\right)^2}.$$

We need to determine its sign under the condition $c \le \eta(q,\theta)$ and $q(4-q)(1-q)\theta > 2$,. Clearly, when $q < 0.465$, the sign is always positive since $4-10q+3q^2 > 0$ and $4-8q+q^2 > 0$. When $q > 0.465$, it is hard to determine the sign. However, numerical examples illustrate that if *q* is medium, the rate is decreasing in *q* when *c* is small while increasing in *q* when *c* is big, while the rate is always decreasing if *q* is high.

In the first example, let $q = 0.5$, $\theta = 5$, we thus have $\eta(q,\theta) = 0.345$ and $\partial\left(D_p \big/ \left(D_o + D_p\right)\right)\big/\partial q < 0$ when $c < 0.192$ and $\partial\left(D_p \big/ \left(D_o + D_p\right)\right)\big/\partial q > 0$ when $0.192 < c < \eta(q,\theta) = 0.345$. In the second example, let $q = 0.47$, $\theta = 5$, we thus have $\eta(q,\theta) = 0.340$ and $\partial\left(D_p \big/ \left(D_o + D_p\right)\right)\big/\partial q < 0$ when $c < 0.021$ and $\partial\left(D_p \big/ \left(D_o + D_p\right)\right)\big/\partial q > 0$ when $0.021 < c < \eta(q,\theta) = 0.340$. In the third example, let $q = 0.6$, $\theta = 5$, we thus have $\eta(q,\theta) = 0.320$ and $\partial\left(D_p \big/ \left(D_o + D_p\right)\right)\big/\partial q < 0$ when $c < \eta(q,\theta) = 0.320$. In the fourth example, let $q = 0.9$, $\theta = 10$, (note that $q(4-q)(1-q)\theta > 2$ requires $\theta > 7.169$) we thus have $\eta(q,\theta) = 0.089$ and $\partial\left(D_p \big/ \left(D_o + D_p\right)\right)\big/\partial q < 0$ when $c < \eta(q,\theta) = 0.089$.

Comparing the pattern of the change of the rate of piracy as the quality of pirated products increases between the additive case and the multiplicative case of *c* and *x*, we find that the pattern is almost the same except that now in the additive case there is a range of medium qualities in which the rate of piracy decreases in *q* when *c* is small and increases in *q* when *c* is large.

Thus, the above analysis proves the robustness of our main findings. We verify that our main results are qualitatively invariant with respect to the multiplicative or additive functional form (between c and x) of the cost function.

6. Comments on Welfare

In this model, it is not difficult to see that the total welfare of the society decreases as the degree of IPR protection increases.[23] The idea is when IPR protection is weak, the available products (particularly the pirated ones) become very cheap so that almost everybody in the economy can afford to buy and use it. This unambiguously increases consumer surplus and welfare of the society. In the absence of concerns about R&D incentives it follows from standard economic arguments that increase in competition (here increase in competition due to the presence of the pirate) must be welfare enhancing. However, if we have allowed R&D innovation on quality of the original product, the implication on welfare could have been different. In the framework described here, the quality of the original product is assumed to be constant; and this is possibly consistent with a short-run situation. In general, if the IPR protection is weak in the market, then it is unlikely that the product developer would invest to improve upon the quality of the product. However, this would eventually reduce the utility and hence consumer surplus and welfare in a long-run situation.

7. Conclusion and Extensions

In this paper, we address the issue of piracy or illegal copying or counterfeiting of the original product and Intellectual Property Right (IPR) protections. The original product developer makes costly investment to deter piracy in a given regime of IPR protection. In this environment, we first characterize completely the entry deterrence and entry accommodation equilibrium in the presence of a commercial pirate. We find that it is profitable for the original producer to accommodate the pirate when there is weak IPR protection, while deterring is profitable when the IPR protection is strong. Next, we ask whether the level of deterrence set by the original producer and the degree of IPR

[23] The detailed calculation on this result is available upon request from the authors.

protection are always substitutes or complements in deterring piracy. In order to answer that we find there is actually a non-monotonic relationship between the optimal level of deterrence (chosen by the original producer) and the degree of IPR protection in the economy. The relationship between the rate of piracy and IPR protection is found to be monotonically decreasing whereas the relationship between the rate of piracy and the quality of the pirated product turns out to be non-monotonic. Interestingly, on the other side, from the commercial pirate's point of view, the most profitable way to survive in the market is to produce a pirated product of moderate quality. Our results also throw some light on the incidence of varying rates of piracy across countries and regions, a phenomenon observed empirically. From our model, we conjecture that it is mainly the interactions of three parameters, namely, the consumers' willingness to pay for the product, the quality of the pirated product and the strength of IPR protection in the economy determine the level of piracy in the society.

In this analysis, we took the level of IPR protection as given. A natural extension would be to endogenize that in the model with a view to find the optimal IPR policy. This might also give some explanation on the interesting question why IPR regimes differ across countries in the first place. In future, we also plan to do some empirical analysis to test some of the main findings of this and future analysis.

References

Andres, A. R. (2006), "The Relationship between Copyright Software Protection and Piracy: Evidence from Europe", *Europe Journal of Law and Economics*, Vol. 21, 29-51.

Bae, S. H. and Choi, J. P. (2006), "A Model of Piracy", *Information Economics and Policy*, Vol. 18, 303-320.

Banerjee, D. S. (2003), "Software Piracy: A Strategic Analysis and Policy Instruments", *International Journal of Industrial Organization*, Vol 21, 97-127.

Banerjee, D. S. (2006), "Lobbying and Commercial Software piracy", *European Journal of Political Economy*, Vol. 22, 139-155.

Belleflamme, P. and Picard, P.M. (2007), "Piracy and Competition", *Journal of Economics and Strategy*, Vol. 16, 351-383.

Chen, Y. and Png, I. (2003), “Information Goods Pricing and Copyright Enforcement: Welfare Analysis”, *Information Systems Research*, Vol 14, No. 1, 107-123.

Conner, K.R. and Rumelt, R.P. (1991), Software piracy – An Analysis of Protection Strategies, *Management Science*, Vol. 37,125–139.

Fischer, J.A.V. and Rodriguez Andres, A. (2005), “Is Software Piracy a Middle Class Crime? Investigating the Inequality – Piracy Channel”, Discussion paper 2005-18, University of St. Gallen.

Gopal, R.D. and Sanders L. G., (1998), “International Software Piracy: Analysis of Key Issues and Impacts”, *Information Systems Research*, Vol. 9, No. 4, 380-397.

Holm, H. J. (2003), “Can Economic theory Explain Piracy Behaviour?”, *Topics in Economic Analysis and Policy*, Vol. 3, No. 1 Article 5. (http://www.bepress.com/bejeap).

Husted, B. W. (2000), “The Impact of National Culture on Software Piracy”, *Journal of Business Ethics*, Vol. 26, No. 3, 197-211.

Kiema, I. (2008), “Commercial Piracy and Intellectual Property Policy”, *Journal of Economic Behavior and Organization*, Vol. 68, 304-318.

Kim, J. H., (2007), “Strategic Use of Copyright Protection to Deter Entry”, *The BE Journal of Economic Analysis and Policy*, Vol. 7, Issue 1, 1-17.

Landes, W. M., and R. A. Posner, (1989), "An Economic Analysis of Copyright Law," *Journal of Legal Studies*, 1989, Vol. 18, 325-366.

Lopez-Cunat, J. M. and Martinez-Sanchez, F., (2007), “The Government’s Role in Controlling Commercial Piracy”, Mimeo, Universidad de Alicante.

Marron, D. B. and Steel, D. G., (2000), “Which Countries Protect Intellectual Property? The case of Software Piracy”, *Economic Enquiry*, Vol. 38, No. 2, 159-174.

Peitz, M. and Waelbroeck, P., (2006) “Piracy of Digital Products: A Critical Review of the Theoretical Literature, *Information Economics and Policy*, Vol. 18, 449-476.

Poddar, S. (2005), “Network Externality and Commercial Software Piracy”, Working paper No. 05-16, National University of Singapore.

Salop, S. C. and Scheffman, D. T., (1987), “Cost Raising Strategies”, *Journal of Industrial Economics*, Vol. 36, 19-34.

Shaked, A. and Sutton, J., (1982), Relaxing Price Competition through Product Differentiation, *Review of Economic Studies*, Vol. 49, 3-13.

Shy, O., Thisse, J., (1999), “A Strategic Approach to Software Protection”, *Journal of Economics and Management Strategy*, Vol. 8, 163–190.

Slive, J., Bernhardt, D., 1998. “Pirated for Profit”, *Canadian Journal of Economics*, Vol. 31, 886–899.

Takeyama, L.N., (1994), “The Welfare Implications of Unauthorized Reproduction of Intellectual Property in the Presence of Network Externalities”, *Journal of Industrial Economics*, Vol. 42, 155–166.

Tirole, J. (1988) *The Theory of Industrial Organization*, Cambridge, MA, MIT Press.

Yao, J. T., (2005), “Counterfeiting and an Optimal Monitoring Policy”, *European Journal of Law and Economics*, Vol. 19, 95-114.

Internet Source:

BSA and IDC Global Software: May 2007 – http://www.bsa.org

Time Magazine (2001), “Chasing Shadows”, June 11.

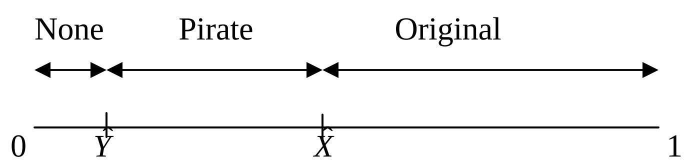

Figure 1: Distribution of buyers when the demand for the pirated product is positive

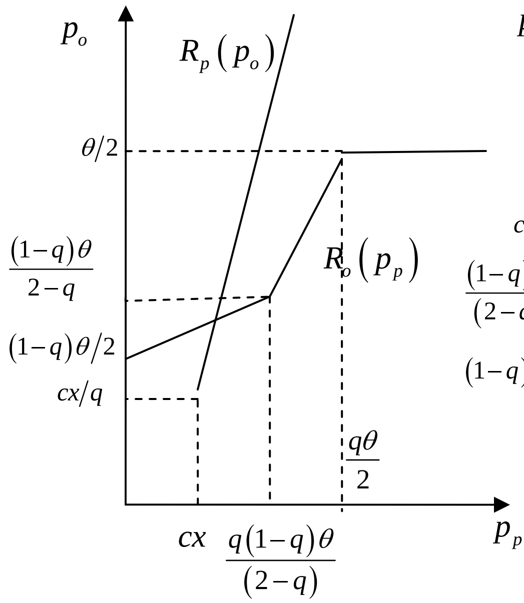

Figure 2a

Best response function
when $x \le q(1-q)\theta/c(2-q)$

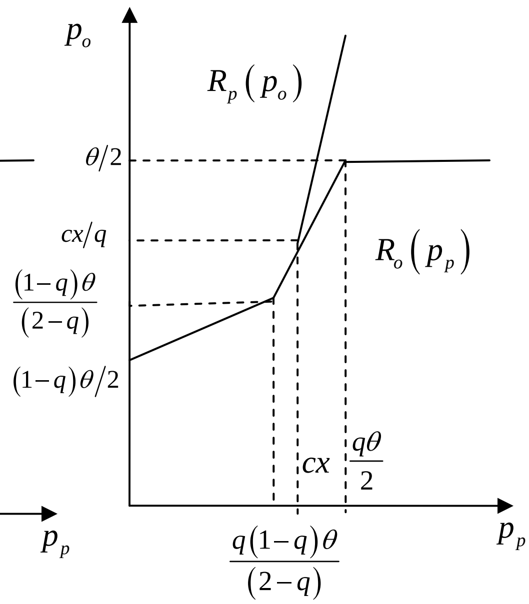

Figure 2b

Best response function
when $q(1-q)\theta/c(2-q) \le x \le q\theta/2c$

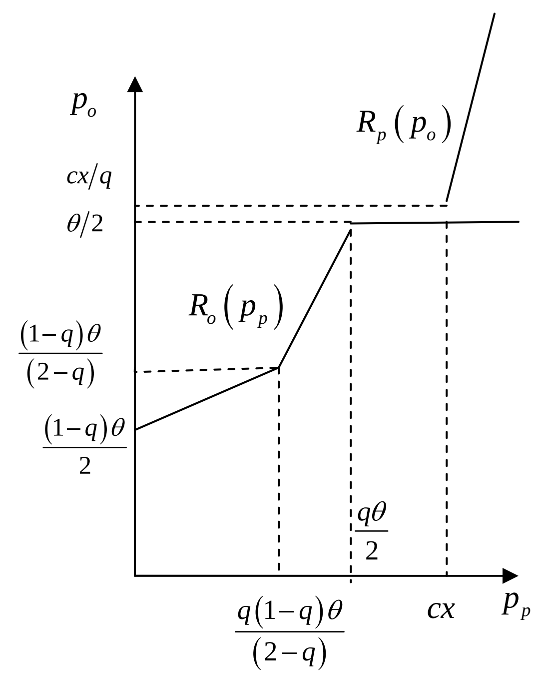

Figure 2c Best response function when $x \ge q\theta/2c$

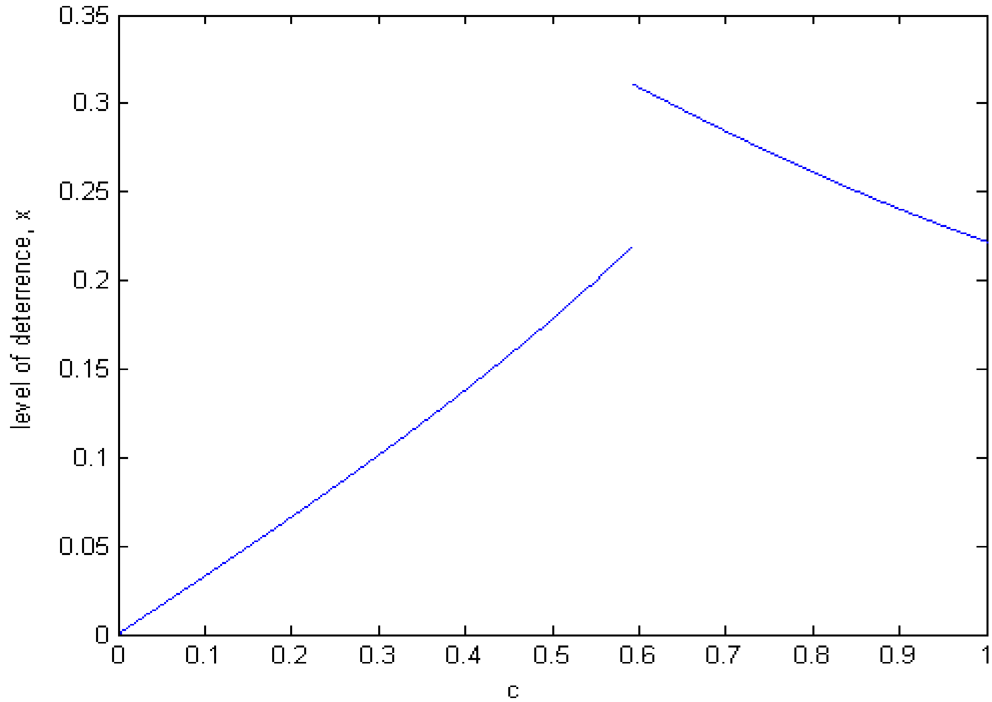

Figure 3 The relationship between the optimal level of deterrence *x* and *c*

$(\theta = 1,\ q = 0.5)$

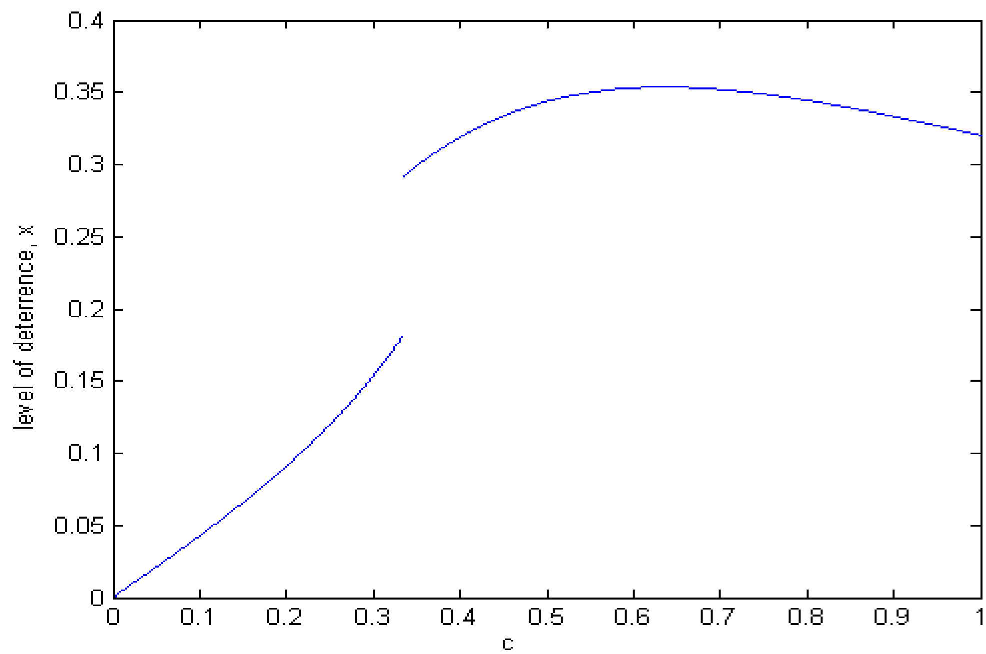

Figure 4 The relationship between the optimal level of deterrence *x* and *c*

$(\theta = 1,\ q = 0.9)$