Piracy, Entry Deterrence and Intellectual Property Rights (IPR) Protection*

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Abstract

In this paper, we address the issue of 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 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.

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 that 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), Oz 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 and end-user 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. The strategic aspects leading to entry deterrence or entry accommodation under commercial piracy that have

[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).

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 influence the decision of the copyright holder to deter or accommodate a pirate. In this paper we hope to fill that gap in the literature. We begin with a model of commercial piracy, where the prevailing IPR protection in the economy plays a major role. It is empirically observed that the degree of IPR protections varies greatly across countries/regions; and most widely between developed and developing countries.[3] We want to incorporate that fact and its impact through a specific parameter in our analysis.

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.[4] 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.[5] The original product developer takes the level/degree of the IPR 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.[6]

[3] The software piracy rate across countries varies a great deal; 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).

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

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

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

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. However, in the comparative statics analysis, we find that there is 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 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.

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. In section 6, we extend our model to analyze end-user piracy. Section 7 discusses briefly on the welfare implications; and section 8 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 price 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 $\pi_o^2 = p_o D_o$,[7] 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). If the pirate is in the market at $t=2$ then its profit function becomes $\pi_p = (p_p - cx)D_p$, 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 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

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

IPR protection mainly consists of two categories: *membership in the international copyright treaties* and *enforcement provisions*.[8]

Note that we have assumed a multiplicative form between c and the level of deterrence x that is chosen by the original firm. Thus, 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.[9]

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, $X \in [0, \theta]$. A consumer's willingness to pay for the product depends on how much he/she values it – measured by X. 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

[8] 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 other hand, 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.

[9] 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 6.

density $1/\theta$ distributed over the interval $[0,\theta]$. Each consumer purchases at most one unit of the good. A consumer's utility function is given as:

$$U = \begin{cases} X - p_o & \text{if buys original product} \\ qX - p_p & \text{if buys pirated product} \\ 0 & \text{if buys none,} \end{cases} \quad [10]$$

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

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

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, $\hat{X}$, who is indifferent between buying the original product and the pirated version is given by:

$$\hat{X} - p_o = q\hat{X} - p_p,$$

or

$$\hat{X} = \left(p_o - p_p\right)/(1-q).$$

[10] 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.

The marginal consumer, $\tilde{Y}$, who is indifferent between buying the pirated product and not buying any product is given by:

$$q\tilde{Y} - p_p = 0 \ ,$$

or

$$\tilde{Y} = p_p / q \, .$$

Thus, the demand for original product is $D_o = \frac{1}{\theta}\int_{\tilde{X}}^{\theta} dx == \frac{(1-q)\theta - (p_o - p_p)}{(1-q)\theta}$ and the demand for pirated product is $D_p = \frac{1}{\theta}\int_{\tilde{Y}}^{\tilde{X}} dx = \frac{qp_o - p_p}{q(1-q)\theta}$.

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 produce is $D_o = (\theta - p_o)/\theta$. Thus, we write the demand functions as the following:

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

and

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

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 $\pi_p = (p_p - cx)D_p$ and the profit function of the original firm is $\pi_o^2 = p_o D_o$. It is straightforward to get the reaction functions of the original firm and the pirate given below:

$$R_o(p_p) = \begin{cases} (p_p + (1-q)\theta)/2 & \text{if } p_p \leq q(1-q)\theta/(2-q) \\ p_p/q & \text{otherwise} \end{cases}, \quad ^{11} \tag{3}$$

and

$$R_p(p_o) = \begin{cases} (qp_o + cx)/2 & \text{if } p_o \geq cx/q \\ \text{any price} \geq cx & \text{otherwise} \end{cases}. \quad ^{12} \tag{4}$$

Note that if the price of the pirated product is high enough (i.e., $p_p \geq q(1-q)\theta/(2-q)$), the original producer's best response is to set price $p_o = p_p/q$ such that there is no demand for the pirated product. Similarly, if the price of the original product is low enough (i.e., $p_o \leq cx/q$), the pirate's best response is to set any price $p_p \geq cx$ such that it does not make a loss. Figure 2 plots the reaction functions for two cases: $x \leq q(1-q)\theta/c(2-q)$ and $x \geq q(1-q)\theta/c(2-q)$. But the pirate's best response to p_o when $p_o \geq cx/q$ is omitted in the figure since the best response is any price no less than *cx*. This does not have any effect on our analysis since the part of the pirate's best response curve does not intersect with the original producer's best response curve.

[Insert Figure 2]

We thus distinguish two cases: $x \leq q(1-q)\theta/c(2-q)$ and $x \geq q(1-q)\theta/c(2-q)$. 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

[11] The inequality follows from the condition $qp_o \geq p_p$ and $p_o = R_o(p_p) = (p_p + (1-q)\theta)/2$.

[12] The inequality follows from the condition $qp_o \geq p_p$ and $p_p = R_p(p_o) = (qp_o + cx)/2$.

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

On the contrary, when $x \geq q(1-q)\theta/c(2-q)$, 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

$$p_o = cx/q, p_p = cx. \quad (6)$$

Note that when $x \geq q(1-q)\theta/c(2-q)$, there is no demand for the pirated product.

When $x \leq q(1-q)\theta/c(2-q)$, 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

$$\pi_o^2 = \left[2(1-q)\theta + cx\right]^2 / (4-q)^2 (1-q)\theta; \quad (7)$$

When $x \geq q(1-q)\theta/c(2-q)$, the demand for the original product is given by $D_o = (q\theta - cx)/q\theta$, and the profit in the second stage is

$$\pi_o^2 = cx(q\theta - cx)/q^2\theta.^{13} \quad (8)$$

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, 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. Again we distinguish two cases: $x \leq q(1-q)\theta/c(2-q)$ and $x \geq q(1-q)\theta/c(2-q)$.

3.3.1 Case (i): $x \leq q(1-q)\theta/c(2-q)$

When $x \leq q(1-q)\theta/c(2-q)$, we get the optimal level of deterrence given below:

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

$$x^* = \begin{cases} \dfrac{4c(1-q)\theta}{(4-q)^2(1-q)\theta - 2c^2} & \text{when } c^2 \le \dfrac{q(4-q)(1-q)\theta}{2} \\ \dfrac{q(1-q)\theta}{c(2-q)} & \text{otherwise} \end{cases}.[14] \tag{9}$$

As we have mentioned earlier, when $x \ge q(1-q)\theta/c(2-q)$, there is no demand for the pirated product. So the necessary condition for the accommodation to occur in equilibrium is $c^2 \le \dfrac{q(4-q)(1-q)\theta}{2}$. Note that this condition also guarantees $x^* > 0$.

It is straightforward to derive the product developer's profit given below:

$$\pi_o = \begin{cases} \dfrac{4(1-q)^2\theta^2}{(4-q)^2(1-q)\theta - 2c^2} & \text{when } c^2 \le \dfrac{q(4-q)(1-q)\theta}{2} \\ \dfrac{(1-q)\theta\left(2c^2 - q^2(1-q)\theta\right)}{2(2-q)^2c^2} & \text{otherwise} \end{cases}. \tag{10}$$

3.3.2 Case (ii): $x \ge q(1-q)\theta/c(2-q)$

When $x \ge q(1-q)\theta/c(2-q)$, we get the optimal level of deterrence given below:

$$x^* = \begin{cases} \dfrac{q(1-q)\theta}{c(2-q)} & \text{when } c^2 \le q(1-q)\theta \\ \dfrac{cq\theta}{q^2\theta + 2c^2} & \text{otherwise} \end{cases}. \tag{11}$$

It is straightforward to derive the product developer's profit given below:

$$\pi_o = \begin{cases} \dfrac{(1-q)\theta\left(2c^2 - q^2(1-q)\theta\right)}{2(2-q)^2c^2} & \text{when } c^2 \le q(1-q)\theta \\ \dfrac{c^2\theta}{2\left(q^2\theta + 2c^2\right)} & \text{otherwise} \end{cases}. \tag{12}$$

[14] Note that if $c = 0$ i.e. when the original firm's investment effort has no effect in deterring piracy, the original firm will not choose any R&D investment in the first place, hence $x^* = 0$.

3.3.3 The original firm's choice

Once we get the original firm's profit in two cases, we can now determine its optimal choice of deterrence level by comparing profits.

First note that $q(1-q)\theta < \frac{q(4-q)(1-q)\theta}{2}$.

When $c^2 \le q(1-q)\theta$, the original firm's profit in case (i) is $\frac{4(1-q)^2\theta^2}{(4-q)^2(1-q)\theta-2c^2}$ and is $\frac{(1-q)\theta\left(2c^2-q^2(1-q)\theta\right)}{2(2-q)^2c^2}$ in case (ii). Since

$$\frac{4(1-q)^2\theta^2}{(4-q)^2(1-q)\theta-2c^2}-\frac{(1-q)\theta\left[2c^2-q^2(1-q)\theta\right]}{2(2-q)^2c^2}=\frac{(1-q)\theta\left[q(1-q)(4-q)\theta-2c^2\right]^2}{2(2-q)^2c^2\left[(4-q)^2(1-q)\theta-2c^2\right]}>0,$$

the original firm's optimal choice is $x^*=\frac{4c(1-q)\theta}{(4-q)^2(1-q)\theta-2c^2}$. By doing so, the firm accommodates the pirate.

When $q(1-q)\theta \le c^2 \le \frac{q(4-q)(1-q)\theta}{2}$, the original firm's profit in case (i) is $\frac{4(1-q)^2\theta^2}{(4-q)^2(1-q)\theta-2c^2}$ and is $\frac{c^2\theta}{2\left(q^2\theta+2c^2\right)}$ in case (ii). Since

$$\frac{4(1-q)^2\theta^2}{(4-q)^2(1-q)\theta-2c^2}-\frac{c^2\theta}{2\left(q^2\theta+2c^2\right)}=\frac{\theta\left[2c^4-q(1-q)(8+q)\theta c^2+8q^2(1-q)^2\theta^2\right]}{2\left[(4-q)^2(1-q)\theta-2c^2\right]\left(q^2\theta+2c^2\right)}$$

$$\begin{cases} \ge 0 & if\ c^2 \le \frac{q(1-q)\left(8+q-\sqrt{q(16+q)}\right)\theta}{4} \\ \le 0 & if\ c^2 \ge \frac{q(1-q)\left(8+q-\sqrt{q(16+q)}\right)\theta}{4} \end{cases},$$

the original firm's optimal choice is $x^* = \frac{4c(1-q)\theta}{(4-q)^2(1-q)\theta - 2c^2}$ when $q(1-q)\theta \le c^2 \le \frac{q(1-q)\left(8+q-\sqrt{q(16+q)}\right)\theta}{4}$ and is $x^* = \frac{cq\theta}{q^2\theta + 2c^2}$ when $\frac{q(1-q)\left(8+q-\sqrt{q(16+q)}\right)\theta}{4} \le c^2 \le \frac{q(4-q)(1-q)\theta}{2}$.

Let us denote $d \equiv \frac{q(1-q)\left(8+q-\sqrt{q(16+q)}\right)\theta}{4}$.

When $c^2 \ge \frac{q(4-q)(1-q)\theta}{2}$, the original firm's profit in case (i) is $\frac{(1-q)\theta\left(2c^2 - q^2(1-q)\theta\right)}{2(2-q)^2 c^2}$ and is $\frac{c^2\theta}{2\left(q^2\theta + 2c^2\right)}$ in case (ii). Since

$$\frac{(1-q)\theta^2\left(2c^2 - q^2(1-q)\theta\right)}{2(2-q)^2 c^2} - \frac{c^2\theta}{2\left(q^2\theta + 2c^2\right)} = \frac{-\theta q^2\left[c^2 - q(1-q)\theta\right]^2}{2(2-q)^2 c^2\left(q^2\theta + 2c^2\right)} < 0,$$

the original firm's optimal choice is $x^* = \frac{cq\theta}{q^2\theta + 2c^2}$.

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* $c^2 \le d$, *the original producer's best strategy is to accommodate the pirate and to choose deterrence level* $x^* = \frac{4c(1-q)\theta}{(4-q)^2(1-q)\theta - 2c^2}$, *price* $p_o = \frac{2(1-q)^2(4-q)\theta^2}{(4-q)^2(1-q)\theta - 2c^2}$ *and earn profit* $\pi_o = \frac{4(1-q)^2\theta^2}{(4-q)^2(1-q)\theta - 2c^2}$

(ii) *When* $c^2 \geq d$ *, the original producer's best strategy is to deter and choose deterrence level* $x^* = \frac{cq\theta}{q^2\theta + 2c^2}$ *, price* $p_o = \frac{c^2\theta}{q^2\theta + 2c^2}$ *and earn profit* $\pi_o = \frac{c^2\theta}{2\left(q^2\theta + 2c^2\right)}$

3.4 An Example

Let's take the following example where $\theta = 1$, $q = 0.5$. The original producer's profits in different cases are represented in figure 3. The solid curve represents the original producer's profit in case (i) when $c \leq \sqrt{\frac{(4-0.5)*0.5*(1-0.5)*1}{2}} = 0.6614$ (i.e. when $c^2 \leq \frac{q(4-q)(1-q)\theta}{2}$, see section 3.3.1); the original producer chooses $x^* = \frac{4c(1-q)\theta}{(4-q)^2(1-q)\theta - 2c^2}$ and accommodates the pirate. The dashed curve represents the profit in case (i) when $c \geq 0.6614$; the original producer chooses $x^* = \frac{q(1-q)\theta}{c(2-q)}$ and deters the pirate. The dotted one and the dash-dot one represent the profit in case (ii) when $c \leq \sqrt{0.5*(1-0.5)*1} = 0.5$ (i.e. when $c^2 \leq q(1-q)\theta$) and when $c \geq 0.5$ respectively; the original producer chooses $x^* = \frac{q(1-q)\theta}{c(2-q)}$ and $x^* = \frac{cq\theta}{q^2\theta + 2c^2}$ respectively and deters the pirate. From this figure, we can see that the original producer's optimal strategy is to accommodate the pirate (when $c \leq \sqrt{\frac{0.5*(1-0.5)(0.5+8-\sqrt{0.25+16*0.5}}{4}} = 0.5931$) or deter the pirate as in case (ii) with high deterrence level $x^* = \frac{cq\theta}{q^2\theta + 2c^2}$ (when $c \geq 0.5931$). Note that we have not completely drawn the original producer's profits in case (ii) with low deterrence level since the profits are relatively low (even negative for some range of *c*).

[Insert Figure 3]

4. Comparative Statics

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

When $c^2 \le d$, i.e. when the original firm always accommodates the pirate, we have

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

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 later effect turns out to be more beneficial than cost saving to the original producer, when it accommodates entry.

When $c^2 \ge d$, i.e. when the original firm deters the pirate, we have

$$\frac{\partial x^*}{\partial c} = \frac{\partial}{\partial c}\left(\frac{cq\theta}{q^2\theta + 2c^2}\right) = \frac{q\theta\left(q^2\theta - 2c^2\right)}{\left(q^2\theta + 2c^2\right)^2} > 0 \quad if\ c^2 < \frac{q^2\theta}{2}$$

$$< 0 \quad if\ c^2 > \frac{q^2\theta}{2}.$$

We first compare d and $\frac{q^2\theta}{2}$. Computations yield $d > \frac{q^2\theta}{2}$ when $q < 0.7239$; and $d < \frac{q^2\theta}{2}$ when $q > 0.7239$. Thus we have the following result under deterrence.

Lemma 1

(i) *When* $q < 0.7239$, $\frac{\partial x^*}{\partial c} < 0$ *is true; however,*

(ii) *When* $q > 0.7239$, $\frac{\partial x^*}{\partial c} > 0$ *as long as* $d < c^2 < \frac{q^2\theta}{2}$, *and* $\frac{\partial x^*}{\partial c} < 0$ *when* $c^2 > \frac{q^2\theta}{2}$. *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, and 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 $q\sqrt{\frac{\theta}{2}}$ and after that, reduce x when c increase sufficiently.

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 4 and 5 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 4 and 5]

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 $\frac{D_p}{D_o + D_p}$ to measure the rate of piracy. Thus the higher the ratio, the higher will be the rate of piracy.

When $c^2 \le d$, i.e. when the original firm accommodates the pirate, we know $x^* = \frac{4c(1-q)\theta}{(4-q)^2(1-q)\theta - 2c^2}$. In this case, $D_o = \frac{2(1-q)(4-q)\theta}{(4-q)^2(1-q)\theta - 2c^2}$, $D_p = \frac{q(1-q)(4-q)\theta - 2c^2}{q\left[(4-q)^2(1-q)\theta - 2c^2\right]}$ and the ratio is $\frac{D_p}{D_o + D_p} = \frac{q(1-q)(4-q)\theta - 2c^2}{3q(1-q)(4-q)\theta - 2c^2}$, which is clearly decreasing in c.

When $c^2 \ge d$, entry is deterred, 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.[15]

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

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

Since $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) = \frac{3\left(3q^2 - 10q + 4\right)c^2\theta}{\left[3q\left(1-q\right)\left(4-q\right)\theta - 2c^2\right]^2}$ when $c^2 \leq d$, we have the following finding.

Proposition 4

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

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-monotonic relationship. When q is small, it is the reliability effect that dominates; whereas when q is large, the price difference 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.

In the light of the above result, from the commercial pirate's point of view we can conclude the following.

Corollary

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, we need to distinguish two cases: $x \le \frac{q(1-q)\theta}{(2-q)} - c$ and $x \ge \frac{q(1-q)\theta}{(2-q)} - c$. The standard procedure yields the optimal level of deterrence is $x^* = \frac{2\left(c+2(1-q)\theta\right)}{(4-q)^2(1-q)\theta-2}$ if the accommodation occurs in equilibrium. Note that $x^* \le \frac{q(1-q)\theta}{(2-q)} - c$ only if $c \le \frac{q(4-q)(1-q)\theta-2}{(4-q)(2-q)}$. So the necessary condition for the accommodation to occur in equilibrium is $c \le \frac{q(4-q)(1-q)\theta-2}{(4-q)(2-q)}$. If $q(4-q)(1-q)\theta < 2$, accommodation is never optimal. Thus, in the forthcoming analysis, we assume $q(4-q)(1-q)\theta > 2$ which also guarantees $x^* > 0$.

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.

Define

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

Proposition 1A

(i) *When* $c \le d$ *, the original producer's best strategy is to accommodate the pirate and to choose deterrence level* $x^* = \dfrac{2\left(c+2(1-q)\theta\right)}{(4-q)^2(1-q)\theta-2}$.

(ii) *When* $d \le c < q\theta/2$ *, the original producer's best strategy is to deter and choose deterrence level* $x^* = \dfrac{-2c+q\theta}{q^2\theta+2}$ *; when* $c \ge q\theta/2$*, there is no need to deter the pirate strategically. Piracy will be deterred anyway due to exogenous high level of IPR protection.*

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

When $c \le d$, i.e. when the original firm always accommodates the pirate, we have

$$\frac{\partial x^*}{\partial c} > 0.$$

When $c \ge d$, i.e. when the original firm deters the pirate, we have

$$\frac{\partial x^*}{\partial c} < 0.$$

Proposition 2A

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.

5.3 Rate of Piracy

As before, we define the ratio of $\dfrac{D_p}{D_o + D_p}$ to measure the rate of piracy.

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

When $c \geq d$, entry is deterred, 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*)

Simple computation yields

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

We need to determine its sign under the condition $c \leq d$. 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 $d = 0.345$ and $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) < 0$ when $c < 0.192$ and $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) > 0$ when $0.192 < c < d = 0.345$. In the second example, let $q = 0.47$, $\theta = 5$, we thus have $d = 0.340$ and $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) < 0$ when $c < 0.021$ and $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) > 0$ when $0.021 < c < d = 0.340$. In the third example, let $q = 0.6$, $\theta = 5$, we thus have $d = 0.320$ and $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) < 0$ when $c < d = 0.320$. 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 $d = 0.089$ and $\frac{\partial}{\partial q}\left(\frac{D_p}{D_o + D_p}\right) < 0$ when $c < d = 0.089$.

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. Extension: End User Piracy

Under this situation, we assume there is no commercial pirate in the economy. The case of end-users piracy will be more likely for digital products which are easy to copy. Here the consumers (i.e. all potential product users) are the potential pirates.[16] As before, there is one original product developer (monopoly) and consumers' valuations are uniformly distributed over the interval $\left[0,\theta\right]$ with density $1/\theta$. Consumers have the choice to buy the original product from the product developer or they can pirate. The activity of the original product firm remains exactly the same as before, except that now it targets the end user pirates to stop piracy as opposed to commercial pirate that we have seen before. However, unlike before, here the original firm does not face any direct competition from anybody in the market; instead, it stands to lose its potential market because of end user pirates. Under this circumstance to limit/stop piracy, it invests to raise the cost of piracy to the end users.[17]

Thus a consumer's utility function is given as:

$$U = \begin{cases} X - p & \text{if buys original product} \\ qX - cx & \text{if pirates original product} \\ 0 & \text{otherwise,} \end{cases}$$

[16] An alternative explanation which is also consistent with this scenario would be when there is a competitive fringe of commercial pirates (i.e. larger number of identical commercial pirates) and each pirate makes zero profit due to perfect competition among them. Although the working for this case would be little different from the end-user piracy case, however, it can be easily verified that there will be no change in the final results (working is available upon request).

[17] Here, we do not need the two period time structure as before, everything can be formulated within a single period without loss of generality. There is no strategic game here, it's a monopoly analysis.

where x is the level of deterrence for piracy from the original producer and $c > 0$ is the exogenous cost parameter as before measuring the degree of IPR protection.

6.1 Deriving Demand of the Original and Pirated Product

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.

The marginal consumer, $\hat{X}$, who is indifferent between buying the original product and pirating is given by $\hat{X} = \dfrac{p-cx}{1-q}$. The marginal consumer, $\hat{Y}$, who is indifferent between pirating the product and not buying any product is given by $\hat{Y} = \dfrac{cx}{q}$. Thus, the demand for the original firm is $D_o = \dfrac{1}{\theta}\int_{\hat{X}}^{\theta} dx = \dfrac{(1-q)\theta-(p-cx)}{(1-q)\theta}$ and the demand for the pirated product is $D_p = \dfrac{1}{\theta}\int_{\hat{Y}}^{\hat{X}} dx = \dfrac{qp-cx}{q(1-q)\theta}$.

6.2 Choice of Optimal Price and Level of Deterrence by the Product Developer

When we derive the demand for the original firm and for the pirated product, we have implicitly assumed $pq \geq cx$ so that the demand for the pirate product is nonnegative. The developer maximizes its net profit subject to this constraint. So the developer's profit maximization problem is

$$\max_{p,x} \pi_o = pD_o - c_o(x) = p\left(\frac{(1-q)\theta-(p-cx)}{(1-q)\theta}\right) - \frac{1}{2}x^2 .$$
$$s.t. \quad pq \geq cx$$

Solving above we get the following result.

Proposition 5

(i) When $c^2 \le q(1-q)\theta$*, the optimal price is* $p^* = \frac{(1-q)^2\theta^2}{2(1-q)\theta - c^2}$ *and the optimal level of deterrence is* $x^* = \frac{c(1-q)\theta}{2(1-q)\theta - c^2}$

(ii) When $c^2 \ge q(1-q)\theta$*, the optimal price is* $p^* = \frac{c^2\theta}{q^2\theta + 2c^2}$ *and the optimal level of deterrence is* $x^* = \frac{cq\theta}{q^2\theta + 2c^2}$.

6.3 Deterrence and Non-Deterrence of Piracy

To deter piracy completely, the developer can also choose a price sufficiently low such that $pq < cx$. But this is not profitable. Given that piracy is completely deterred, the demand for the product firm is $(\theta - p)/\theta$, which is independent of *x* and decreases in *p*, the developer will choose a price such that $pq = cx$. Thus we state the condition for no piracy in the following result.

Proposition 6

When the pirates are the end users and stopping piracy is a costly activity to the product firm, the piracy will actually be stopped if $c^2 \ge q(1-q)\theta$ *. Otherwise there will be piracy.*

Proof: Follows directly from part (ii) of proposition 5.

7. Discussion 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.[18] 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

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

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.

8. Conclusion

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. However, we find 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. In the last part of the paper, we extend our analysis to end-users piracy. Our future research plan is to test some of the main findings of this analysis empirically.

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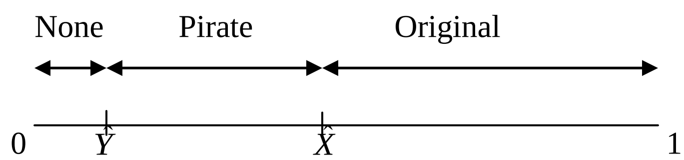

Figure 1: Distribution of buyers when the demand for the pirated product is positive

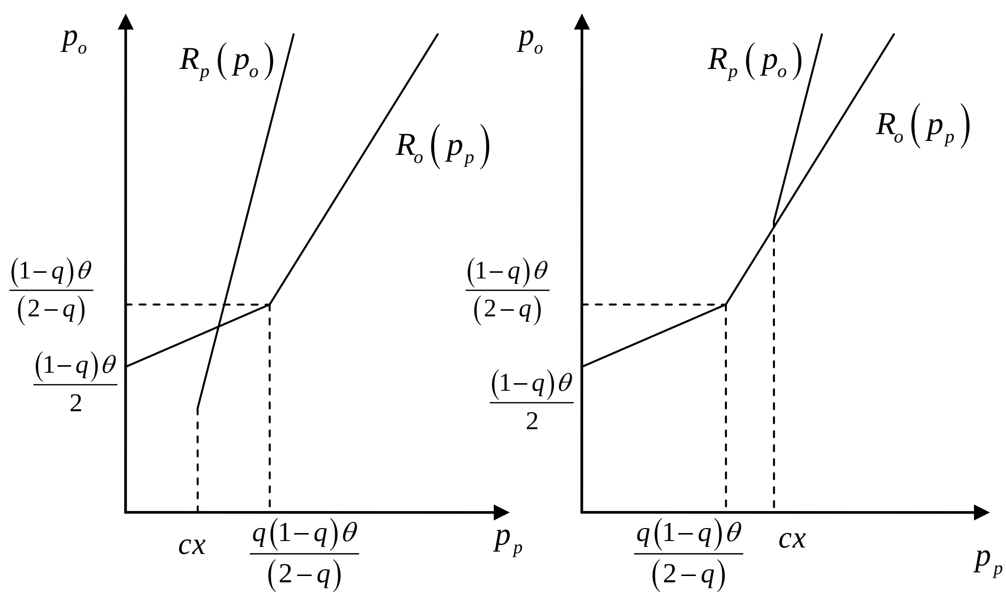

Figure 2a
Best response function
when $x \le q(1-q)\theta/c(2-q)$

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

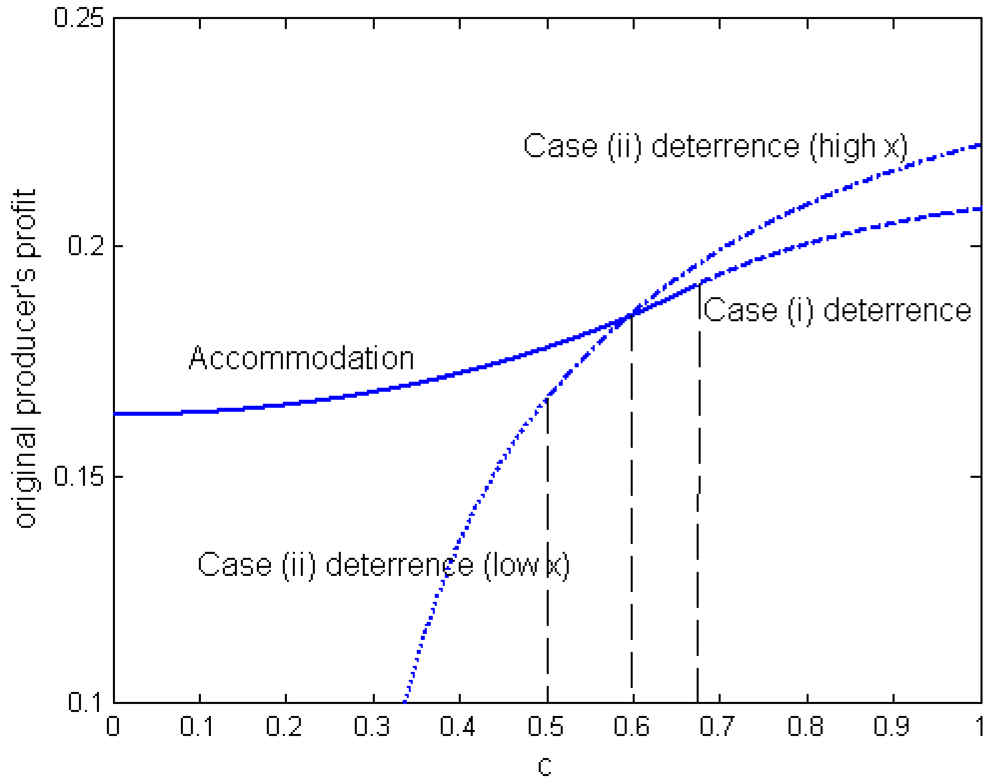

Figure 3 The Original Producer's Profits in Different Cases ($\theta = 1,\ q = 0.5$)

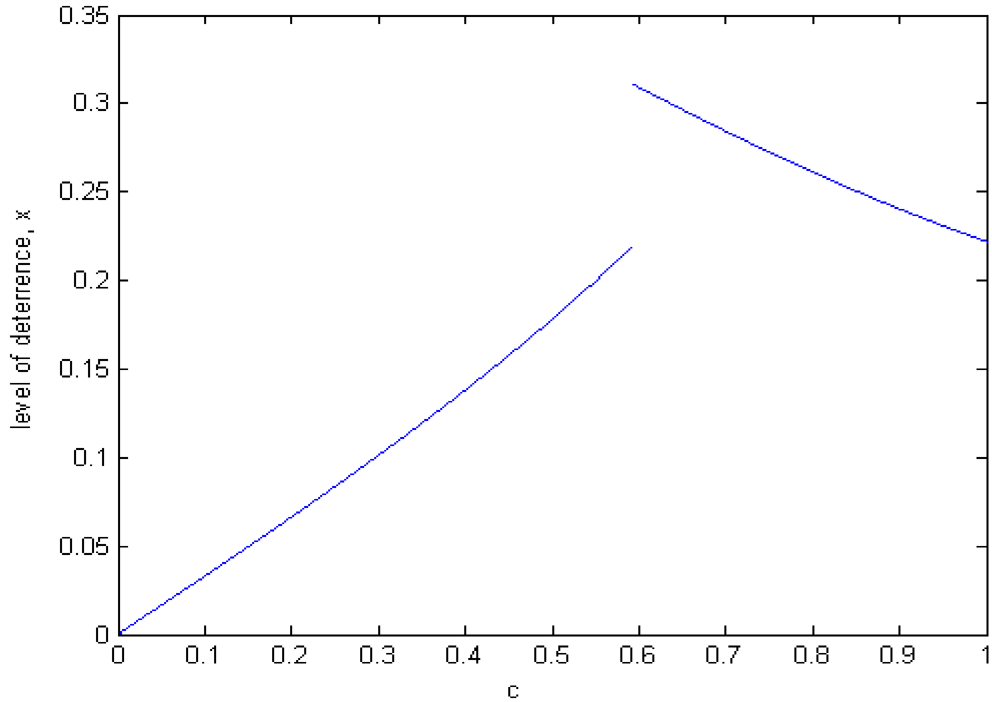

Figure 4 The relationship between the optimal level of deterrence *x* and *c*

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

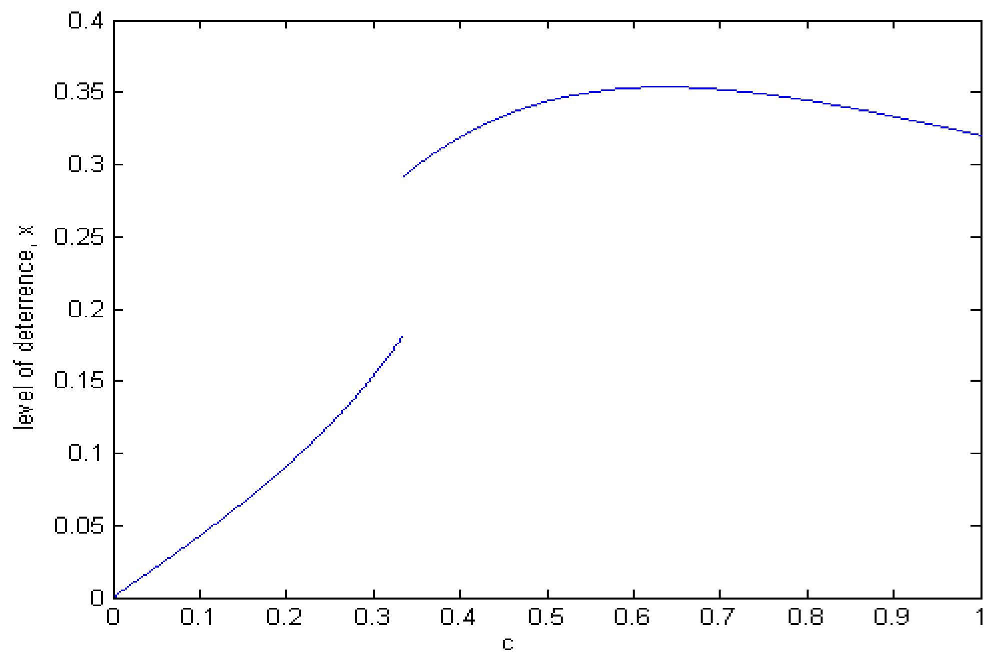

Figure 5 The relationship between the optimal level of deterrence *x* and *c*

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