Economics of Digital Piracy – Some Thoughts and Analysis
The Case of Software and Movie Piracy

(Preliminary and Incomplete Version)

Sougata Poddar
Department of Economics
National University of Singapore
10 Kent Ridge Crescent
Singapore 119260

E-mail: ecssp@nus.edu.sg

September 2006

Abstract (short)

It is said that we are living in the age of information. The usage of computer, internet, e-mails, and various software became an integral part of our life. In this age of information revolution, one thing that is also significantly drawing our attention is the occurrence of large scale digital piracy. Digital piracy and its implication on the economy and on the society is a major concern for both developed and developing countries; and more so in developing countries where the piracy rates are generally very high. The aim of this paper is to provide some analysis that would give us some direction to understand the behaviour of the economic agents participating in this digital economy. The case of software piracy and movie piracy is discussed here.

Keywords: Software piracy, Movie piracy, Copyright Violations, Network externality, Deterrence, Product reliability

Abstract (long)

Abstract for Software Piracy

Part a: Network Externality and Commercial Software Piracy

Contrary to the earlier findings under end-users piracy where the existence of strong network externality was shown to be a reason for allowing limited piracy, we find when the piracy is commercial in nature the optimal policy for the original software developer is to protect its product irrespective of the strength of network externality in the software users market.

Part b: On Software Piracy Rates

The pervasiveness of the illegal copying of software is a worldwide phenomenon. However, there is a marked difference in the piracy rates between developed and developing countries. In this paper, we develop a theoretical model to explain this feature. In this model, the original software firm makes investments to increase the cost of piracy to the software pirate(s). The existence (or non-existence) of piracy in our model comes out endogenously.

Abstract for Movie Piracy

In recent years, much research and studies have been done on software and music piracy but with little on movie piracy. However, with rapid technological advances, the present trend of movie piracy has certainly drawn the attention of movie producers who fear for their work and profits being jeopardized. In order to see the impact movie piracy on the box-office (i.e. the movie theatres) we develop a simple theoretical model to address this issue. We find while protection from any kind of piracy is always the first best for the movie producer; no protection at all is the first best for the consumers and the society. Thus, to balance the interests of the movie producers as well as the consumers we propose a scenario of partial protection. In a dynamic setting partial protection means delaying piracy. In this scenario of partial protection consumer surplus and overall welfare is enhanced while movie producers ensure profitability and retain the incentives to make new movies.

1. Introduction

It is said that we are living in the age of information. The usage of computer, internet, e-mails, and various software became an integral part of our life. The emerging market of e-commerce and e-business are gradually taking the center stage among all business transactions. This new information revolution is greatly influencing our day-to-day life in various ways. Among these developments, one thing that is also significantly drawing our attention in this new environment is the occurrence of large scale digital piracy. The issue is debated in academic journals to policy studies to newspaper articles. Digital piracy and its implication on the economy and on the society is a major concern for both developed and developing countries; and more so in developing countries where the piracy rates are generally very high. It is not hard to see that the emergence of digital economy and the impact of digital piracy are going to make a big difference in shaping up the future of all these economies. Given this backdrop, the aim of this paper is to provide some thoughts (and analysis) that would give us some direction to understand the behaviour of all the economic agents participating in this digital economy. In this paper, we will discuss issues related to software piracy and movie piracy.

It is understood that the pervasiveness of the illegal copying of digital products (which includes software, music and movie) is having a profound effect on the software, music and movie industry as well as on the users of the digital products. It is also having a tremendous effect on the innovations of new technologies and the development of digital intellectual properties. Software, music or movie piracy is rampant because of the very nature of the product. The production of the original copy requires large development cost, but once developed, the manufacturing costs of fabricating a copy are almost negligible. In other words, replicated copies of the original incur zero costs and this is precisely why digital piracy presents such a lucrative and effective option for the commercial copiers or private users.

2. Software Piracy

It is reported that every year software piracy is costing billions of dollars to the software industry. In the year 2003, revenue losses to the global software industry due to piracy were estimated at $ 13.08 billion. Among the new business software applications installed worldwide during 2002, 39% - were pirated. (Source: Business Software Alliance, 2004). Given this fact, the conventional wisdom would suggest to take a harsh approach on piracy of software. But at the same time, the legal software products are almost beyond the purchasing capability of the average software users in the developing world. So piracy remains the only way out in those regions. It is also true that easy availability of the (pirated) software products in the developing markets increases the know-how and usage of the software products. This in turn helps the software companies to sell their products in those markets more successfully in the future. Thus, a complex relationship between the software buyers and sellers make the software market and the industry an interesting place to study. In the following analysis we focus on two particular aspects related to software piracy.

(i) Network externality and commercial piracy
(ii) Differing software piracy rates across countries/regions.

(a) Network Externality and Commercial Software Piracy

There are some studies in the literature (see Conner and Rumelt (1991), Takeyama (1994), Slive and Bernhardt (1998), Shy and Thisse (1999) among others) which provide us a economic reason behind widespread *end-user piracy (or private coping)*. For example, in some situations the original software developer may not want to stop piracy even when it has the means to do so simply because it can actually be profitable for the software developer to allow limited piracy. The arguments to establish this result basically stands on the feature of network externality that is widely observed in the software users market. It has been shown that when the effect of network externality is strong, allowing piracy by the original software developer can be a profitable option.

However, another type of software piracy that also considerably draws our attention is *commercial or retail piracy* and none of the above studies explicitly discuss about the case of commercial piracy and the impact of network externality on it.[1] Commercial piracy is prevalent in most developing countries where the laws against piracy or in general enforcement against copyright violations are rather weak.[2] Under commercial piracy, there is a pirate or a group of small pirates operates from make-shift shops, copies the original software and sells to the consumers.[3] In other words, the pirate(s), in some sense competes with the original producer in the same market by providing a cheaper variety of the original product. The pirate's product usually is not guaranteed, it does not come with any supporting service, and sometimes it is also not fully reliable. But at the same time, it comes at a lot cheaper price than the original one, and as a result consumers get easily attracted to it.[4]

Now when the nature of piracy is of this type (i.e. commercial type as opposed to end-user type), we want to see the effect of network externality on the existence of piracy and ask the question what would be the optimal policy of the original software developer in regard to piracy and protection. The question is interesting as we will see later that the presence of the commercial pirate expands the market for the original product (through network effect), which is naturally beneficial for the original developer. However, due to competition there is a dampening effect on price as both firms compete in the same market selling (vertically) differentiated products. Thus the question is how the positive effect on demand expansion of the original developer and the negative affect on price

[1] Banerjee (2003) studies commercial piracy, however, the main focus of the paper is to see the impact of monitoring policy over piracy on the welfare of the society. Effects of various policy instruments on aggregate welfare under end-users piracy are studied by Chen and Png (2003), Gayer and Shy (2003) among others. For a comprehensive study on the issue of copyright and economic theory see Watts (2000).

[2] Widespread corruptions, weak legal systems, bribery are some of the reasons for that. Also in most developing countries, where the computer literacy and the technological know-how are still very low among the average people, buying a ready-made pirated product at a cheap price is more effective.

[3] With advanced and sophisticated technological methods, pirated software copies or even copies of copies become almost if not perfectly identical to an original one.

[4] Software users market is quite heterogeneous in nature. There are heavy users (high valued consumers) to very light users (low valued consumers) of software. Heavy users are likely to depend on reliable product, whereas low valued consumers naturally have higher incentive to buy a pirated copy at a cheaper price.

combine together. Our result shows that under such circumstances protection as opposed to allowing piracy is always optimal for the original software developer irrespective of the strength of network externality in the software users market. Thus, to see the effect of network externality on commercial software piracy we get a result that is quite different from the case of end-users piracy.

The Model of Commercial Piracy

We start our analysis with an original software firm and one commercial pirate. Later we extend our analysis when there is a group of identical pirates provide a competition to the original software firm. Consumers can buy the original product at a higher price from the software firm or can buy the pirated version from the pirate at a cheaper price. The pirate has the technology to copy the original software and we assume the cost of copying the software is zero. We assume the probability that a pirated software works is q, $q \in (0,1)$ and this probability is common knowledge.[5] We interpret q in the following ways. q serves as a proxy for the quality of the pirated software. Usually when the consumer gets a pirated copy, it does not come with the supporting services, or sometimes some applications may be missing in the pirated version. There is no warranty on the pirated software. Hence, the consumer enjoys the benefit of the pirated software only with probability q. The original software is fully guaranteed to work. p_O and p_P are the prices of the original and pirated software respectively. It must be true that $p_O > p_P$.

There is a continuum of consumers indexed by X, $X \in [\theta_L, \theta_H]$, $\theta_H > \theta_L \geq 0$. A consumer's willingness to pay for the software depends on how much he/she values it – measured by X. A high value of X means higher valuation for the software and low value of X means lower valuation for the software. Therefore, one consumer differs from another on the basis of his/her valuation for the particular software. Valuations are uniformly distributed over the interval $[\theta_L, \theta_H]$ and the size of the market is normalized to 1.

Assumption 1: We assume $\theta_H \geq 2\theta_L$ to ensure enough heterogeneity in the market.

A consumer's utility function is given as:

$$U = \begin{cases} X - p_O & \text{if buys original software} \\ qX - p_P & \text{if buys pirated software} \\ 0 & \text{if buys none} \end{cases}$$

Next we introduce the feature of network externality. Since the pirated product is available at a cheaper price, a number of low valued consumers will have an incentive to actually buy the pirated product. This in turn will increase the total number of software users in the society which in turn will intensify the network effect. The increase in

[5] $q = 0$ will eliminate the pirated product, while $q = 1$ will make two products identical. Note $q = 1$ is never possible due to the reasons described above.

network effect increases the value of the (pirated or original) software for any potential buyer.

Under this circumstance, we will consider two situations in the forthcoming analysis. First, where the original developer protects its software (hence no piracy is possible), and secondly, where the original developer does not protect. For simplicity, here we assume that protection is costless and the original developer can just install a protective device into the software that makes coping impossible. Thus, the original developer can choose to keep its software protected or unprotected.

Software Protection (No Piracy)

Without piracy, consumers would choose only between either buying the original one or not buying at all.

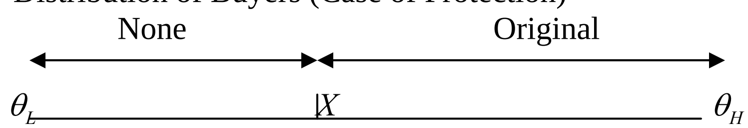
Thus a consumer's utility in the presence of network externality is given by:

$$U = \begin{cases} X + \gamma D_{NP} - P_{NP} & \text{if buys original software} \\ 0 & \text{if buys none} \end{cases}$$

D_{NP} denotes the total demand of the software under protection (i.e. no piracy) [6] and P_{NP} denotes the price of the software. Now $\gamma \geq 0$ is a coefficient which measures the importance of network size to the software users. It can be viewed as the degree or intensity of network externalities. For example, higher γ implies stronger effect of network externality, whereas when γ is close to zero, it implies almost no effect of network externality at all.

Assumption 2: We assume $\theta_H > \theta_L + \gamma$, to have well defined demand and prices in the subsequent analysis.

Figure 1: Distribution of Buyers (Case of Protection)



X is the marginal consumer who is indifferent between buying the original software and not buying any software at all:

$X + \gamma D_{NP} - P_{NP} = 0$

$X = P_{NP} - \gamma D_{NP}$

Demand for the original software is:

$$D_{NP} = \int_X^{\theta_H} \frac{1}{\theta_H - \theta_L} dx = \frac{\theta_H - P_{NP} + \gamma D_{NP}}{\theta_H - \theta_L}$$

$$\Rightarrow D_{NP} = \frac{\theta_H - P_{NP}}{\theta_H - \theta_L - \gamma}$$

[6] Using notation "NP" in the subscript to denote "no piracy".

Note that assumption 2 ensures the demand is positive.
The monopolist's profit is:

$$\pi_{NP} = P_{NP} \,.\, D_{NP} = P_{NP} \,.\, \frac{\theta_H - P_{NP}}{\theta_H - \theta_L - \gamma}$$

Solving for the profit-maximizing monopolist price, we get: $P^*_{NP} = \frac{\theta_H}{2}$

And demand is:

$$D^*_{NP} = \frac{\theta_H}{2(\theta_H - \theta_L - \gamma)} \qquad (1)$$

Note that when $\gamma = \frac{\theta_H - 2\theta_L}{2}$ (assumption 1 makes this expression positive)

$D^*_{NP} = 1$ i.e. the full market is served.

Hence the pricing policy of the monopolist is:

$$P^*_{NP} = \frac{\theta_H}{2} \quad \text{when } 0 \le \gamma < \frac{\theta_H - 2\theta_L}{2} \qquad (2)$$

$$= \theta_L + \gamma \quad \text{when } \gamma \ge \frac{\theta_H - 2\theta_L}{2} \qquad (3)$$

The profit of the monopolist software firm is:

$$\pi^*_{NP} = \frac{\theta_H^2}{4(\theta_H - \theta_L - \gamma)} \quad \text{when } 0 \le \gamma < \frac{\theta_H - 2\theta_L}{2} \qquad (4)$$

$$= \theta_L + \gamma \quad \text{when } \gamma \ge \frac{\theta_H - 2\theta_L}{2} \qquad (5)$$

Now consider the case when piracy is allowed by the software firm and there is a commercial pirate.

Allowing Software Piracy

Here consumer's utility is given by:

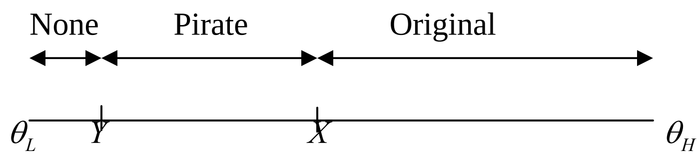
$$U = \begin{cases} X + \gamma D_O + q\gamma D_P - p_O\ ^{7} & \text{if buys original software} \\ qX + q\gamma D_O + q^2\gamma D_P - p_P\ ^{8} & \text{if buys pirated software} \\ 0 & \text{if buys none} \end{cases}$$

D_O, p_O and D_P, p_P are the demand and prices for the original and pirated software respectively. As mentioned earlier, q is the probability that the pirated software works.

[7] Since the consumer buys original software, he gets to enjoy the benefit X and the network externality generated by those who also buy original software with certainty. However, he only gets to enjoy the network created by those who buy pirated software with probability q since only there is only a q chance that it works.

[8] Since this consumer buys pirated software, he gets to enjoy the benefit and the network effect created by both legal and illegal users if and only if his software works.

Figure 2: Distribution of Buyers (Case of Non-Protection)



Like before, the marginal consumer X, who is indifferent between buying the original software and the pirated version is given by:

$$X + \gamma D_O + q\gamma D_P - p_O = qX + q\gamma D_O + q^2\gamma D_P - p_P$$

$$X = \frac{p_O - p_P}{1-q} - \gamma\left(D_O + qD_P\right)$$

The marginal consumer Y, who is indifferent between buying the pirated software and not buying any software at all is given by:

$$qY + q\gamma D_O + q^2\gamma D_P - p_P = 0$$

$$Y = \frac{p_P}{q} - \gamma\left(D_O + qD_P\right)$$

The demand for the original software is given by:

$$D_O = \int_X^{\theta_H} \frac{1}{\theta_H - \theta_L} dx$$

The demand for pirated software is given by:

$$D_P = \int_Y^{X} \frac{1}{\theta_H - \theta_L} dx = \frac{1}{\theta_H - \theta_L}\left[\frac{qp_O - p_P}{q(1-q)}\right]$$

Thus, $D_O = \dfrac{1}{\theta_H - \theta_L - \gamma}\left[\theta_H - \dfrac{p_O - p_P}{1-q} + \dfrac{\gamma q}{\theta_H - \theta_L}\left(\dfrac{qp_O - p_P}{q(1-q)}\right)\right]$ (6)

The original firm and the pirate compete by choosing price strategically. The respective reaction functions are given by:

$$p_O\left(p_P\right) = \frac{\theta_H - \theta_L}{2\left(\theta_H - \theta_L - \gamma q\right)}\left[\theta_H\left(1-q\right) + p_P\left(1 - \frac{\gamma}{\theta_H - \theta_L}\right)\right]$$

$$p_P\left(p_O\right) = \frac{qp_O}{2}$$

Hence, Nash Equilibrium prices are:

$$p_O^* = \frac{2\left(\theta_H - \theta_L\right)\left(1-q\right)\theta_H}{\left(\theta_H - \theta_L\right)\left(4-q\right) - 3\gamma q} \tag{7}$$

$$p_P^* = \frac{q\left(1-q\right)\left(\theta_H - \theta_L\right)\theta_H}{\left(\theta_H - \theta_L\right)\left(4-q\right) - 3\gamma q} \tag{8}$$

Equilibrium demands are:

$$D_O^* = \frac{\theta_H}{\left(\theta_H - \theta_L - \gamma\right)}\left[\frac{2\left(\theta_H - \theta_L - \gamma q\right)}{\left(\theta_H - \theta_L\right)\left(4-q\right) - 3\gamma q}\right] \tag{9}$$

$$D_P^* = \frac{\theta_H}{(\theta_H - \theta_L)(4-q) - 3\gamma q}$$

(10)

The profit of the original software firm is:

$$\pi_O^* = \frac{4\theta_H^2(\theta_H - \theta_L)(1-q)(\theta_H - \theta_L - \gamma q)^2}{(\theta_H - \theta_L - \gamma)\left[(\theta_H - \theta_L)(4-q) - 3\gamma q\right]^2}$$

(11)

and that of the pirate is: $\pi_P^* = \dfrac{\theta_H^2 q(1-q)(\theta_H - \theta_L)}{\left[(\theta_H - \theta_L)(4-q) - 3\gamma q\right]^2}$ (12)

There will be an upper bound of the network effect γ for which $D_O^* + D_P^* = 1$. Suppose that upper bound is $\hat{\gamma}$. Now $\hat{\gamma}$ is necessarily less than $\dfrac{\theta_H - 2\theta_L}{2}$ (see previous section) as the size of the market served under duopoly is unambiguously larger than the size of the monopoly market under protection. Hence, when $0 \le \gamma < \dfrac{\theta_H - 2\theta_L}{2}$, comparisons between demands ((1) and (9)); prices ((2) and (7)); and profits ((4) and (11)) under the previous monopoly and the present duopoly case are legitimate. The following two results summarize the impact of the presence of the commercial pirate in the market of the software developer.

Lemma 1

The demand for the original firm under piracy is higher than its demand under protection, while price under piracy is lower than under protection.
Formally, $D_O^* > D_{NP}^*$ *and* $p_O^* < P_{NP}^*$.

Proof: From (1) and (8), we get $D_O^* - D_{NP}^* = \dfrac{\theta_H q}{2\left[(\theta_H - \theta_L)(4-q) - 3\gamma q\right]} > 0$

From (2) and (6) we have,

$$P_{NP}^* - p_O^* = \frac{3\theta_H(\theta_H - \theta_L - \gamma)q}{2\left[(\theta_H - \theta_L)(4-q) - 3\gamma q\right]} > 0.$$

Interestingly, we note that the presence of the commercial pirate has a positive effect on the original firm's demand. Allowing the pirate expands the market for the original product. However, due to competition there is a dampening effect on price as both firms compete in the same market selling differentiated products.

Lemma 2 $D_O - D_{NP}$ *is an increasing function of* γ.

Thus increase in the demand for the software developer due to presence of the pirate increases with the intensity of network externality.

Optimal Choice: Protection versus Non-Protection

We are interested to see how the positive effect on demand of the original software firm and the negative affect on price combine together to determine the net effect on the profit of the software firm.

Proposition 1

Given a choice between employing protection and non-protection, it is always profitable for the original software developer to protect its software from the commercial pirate. Formally, $\pi_{NP}^{*} > \pi_{O}^{*}$ for all $\gamma \geq 0$.

Proof: <u>Case 1:</u> $0 \leq \gamma < \frac{\theta_H - 2\theta_L}{2}$

$$\pi_{NP}^{*} - \pi_{O}^{*} = \frac{\theta_H^2}{4(\theta_H - \theta_L - \gamma)} - \frac{4\theta_H^2(\theta_H - \theta_L)(1-q)(\theta_H - \theta_L - \gamma q)^2}{(\theta_H - \theta_L - \gamma)\left[(\theta_H - \theta_L)(4-q) - 3\gamma q\right]^2}$$

Now, $\pi_{NP}^{*} > \pi_{O}^{*}$ if $\frac{1}{4} - \frac{4(\theta_H - \theta_L)(1-q)(\theta_H - \theta_L - \gamma q)^2}{\left[(\theta_H - \theta_L)(4-q) - 3\gamma q\right]^2} > 0$

Sufficient condition for the above to be true is $\gamma < \frac{2(\theta_H - \theta_L)}{2+q}$. Now given that $\frac{\theta_H - 2\theta_L}{2} < \frac{2(\theta_H - \theta_L)}{2+q}$ the sufficient condition holds, hence the result.

<u>Case 2:</u> $\gamma \geq \frac{\theta_H - 2\theta_L}{2}$

In this case, full market is served under monopoly as well as duopoly. However, for a given degree of network externality, when original developer is the monopolist and serves the entire market it must earn a higher profit than when it shares the market with a competitor and jointly serves the full market.

Q.E.D.

Thus, we find that the above proposition is true irrespective of the value of γ i.e. irrespective of the strength of network externality. No matter how strong is the network effect, it is never profitable for the original software developer to allow the commercial pirate.

Extension: A Group of Small Pirates

Now we consider the case when there is a group of identical pirates provide a competition to the original software firm. The pirates being small, we assume behave competitively among themselves.

From (6) in section 4 we get the demand for the original form when its chooses a price p_O while its competitor chooses price p_p,

$$D_O = \frac{1}{\theta_H - \theta_L - \gamma}\left[\theta_H - \frac{p_O - p_P}{1-q} + \frac{\gamma q}{\theta_H - \theta_L}\left(\frac{qp_O - p_P}{q(1-q)}\right)\right]$$

Here the competitors are a group of identical pirates who behave competitively among them, thus price $p_p =$ marginal $\text{cost} = 0$. Substituting this in the above expression of demand we get

$$D_O = \frac{1}{\theta_H - \theta_L - \gamma}\left[\theta_H - \frac{p_O}{1-q} + \frac{\gamma}{\theta_H - \theta_L}\left(\frac{qp_O}{(1-q)}\right)\right]$$

Thus, $\pi_O = \dfrac{p_O}{\theta_H - \theta_L - \gamma}\left[\theta_H - \dfrac{p_O}{1-q} + \dfrac{\gamma}{\theta_H - \theta_L}\left(\dfrac{qp_O}{(1-q)}\right)\right]$

Now, maximizing the above profit with respect to p_O, we get

$p_O^* = \dfrac{(\theta_H - \theta_L)(1-q)\theta_H}{2\left[(\theta_H - \theta_L) - \gamma q\right]}$ and $D_O^* = \dfrac{\theta_H}{2(\theta_H - \theta_L - \gamma)}$

Note that above D_O^* is same as D_{NP}^* in (1) in section 3 i.e. demand under no piracy.

Next we show that

$$P_{NP}^* - p_O^* = \frac{\theta_H}{2} - \frac{(\theta_H - \theta_L)(1-q)\theta_H}{2\left[(\theta_H - \theta_L) - \gamma q\right]} = \frac{\theta_H}{2}\left[\frac{q(\theta_H - \theta_L - \gamma)}{\theta_H - \theta_L - \gamma q}\right] > 0 \text{ if } 0 \le \gamma < \frac{\theta_H - 2\theta_L}{2}$$

For $\gamma \ge \dfrac{\theta_H - 2\theta_L}{2}$; $\theta_L + \gamma \ge \dfrac{\theta_H}{2}$, hence $P_{NP}^* - p_O^* > 0$.

Thus $\pi_{NP}^* > \pi_O^*$ for all $\gamma \ge 0$. Hence, we get the same result as in proposition 1.

Conclusion

To see the effect of network externality on commercial software piracy, we find our results are in complete contrast with the previous findings under end users piracy. Under end users piracy, allowing limited piracy by the original software firm is rationalized due to the presence of strong demand network externality. Here we show that under no circumstances i.e. irrespective of the strength of network externality, original software firm would never find it profitable to allow commercial pirate(s). Our result is also independent of the quality and reliability (q) of the pirated copies. In that sense this result of choosing full protection of the software by the original developer under commercial piracy turns out to be robust as well.

(b) Why Software Piracy Rates Differ (Work in progress)

A sketch of the model and some preliminary results.

We observe that the level of piracy across various regions and markets varies a great deal. In some markets, we observe rampant piracy while in some other markets piracy is rare.[9] There exists empirical studies (see Gopal and Sanders (1998, 2000), Husted (2000), Donald and Steel (2000), Holm (2003), Banerjee et. al. (2005), Fischer and Rodriguez (2005)) to explain the varying piracy rates across countries and regions, but to the best of our knowledge no rigorous theoretical framework has been used so far to explain the same phenomenon. In this paper, we attempt to do that. We develop a theoretical model to explain why we may observe varying rates of piracy across nations, and more specifically, between the developed and developing nations.

In this model the software firm itself undertakes costly deterrence activity in the form of R&D to stop piracy. Unlike any previous study, we explicitly model how the optimal level of deterrence is actually chosen by the software firm in the presence of piracy. As a result, in our model existence (or non-existence) of piracy comes out endogenously. In the case of commercial piracy, the existence (or non-existence) of piracy comes out as an endogenous outcome of a (dynamic) strategic game between the pirate and the original firm. In the case of end user piracy it is determined by the optimal level of deterrence chosen endogenously by the monopolist software firm.

Under both types of piracy, we find out under what condition piracy will take place and when it can be stopped. 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, which consequently limits/stops piracy. Investing in R&D by the software firm to raise the cost of piracy or the deterrence level to piracy can be done in different ways. For example, the original firm can develop a technology (like putting a protective device into the software), which increases the cost of copying its software. It can invest in R&D to come up with appropriate method and technology to monitor the pirate(s). In this model, we assume costly R&D undertaken by the software firm will increase the pirate's unit cost of producing a copy of the original software. Thus higher the R&D investment, higher is the cost of piracy to the pirate. We also assume costly R&D must be undertaken ahead by anticipating that there will be piracy and before the pirate could actually start its operation.

Raising rival's cost of production in order to induce its rival to exit the industry has been studied earlier by Salop and Scheffman (1983). However, they focused their study in an industry consisting of a dominant firm and a competitive fringe, where the low cost dominant firm can cause injury to the rivals by strategically raising the cost of the fringe firms. Interestingly, further studies of this feature (of raising rival's cost) were not done much in other type of industries or market structures.[10] In this paper, we introduce this feature in a simple duopoly framework under commercial piracy where one competitor (the original firm) endogenously raises the rival's (pirate) cost by undertaking costly R&D investment. We believe apart from the piracy aspect of this paper, studying the strategic option of raising rival's cost endogenously in this fashion is also a contribution to the literature of strategic entry deterrence.

Now, since this investment for deterrence made by the software firm is costly, the question that naturally arises, whether it is profitable to the firm to actually undertake

[9] Piracy rates defined as the ratio of the number of pirated copies to total installed copies, vary from 21 percent in US to 92 percent in Vietnam in the year 2004. (See BSA and IDC Global Software 2005 for a detailed survey on piracy rates in different countries).

[10] The only exception is vertically related markets. See Salinger (1988), Ordover et al. (1990), Sibley & Wiseman (1998), and Banerjee & Lin (2003) for studies on this issue.

such deterrence operation. And if at all it undertakes such deterrence operation, under what circumstances it will be effective. We show that the answers to these questions depend on the overall profitability of the original firm as well as of the pirate and on the net utility of the potential software users. This in turn depends on some basic features of an economy like, valuation gap of the product among the potential software users, the level of the enforcement policy against the pirate (i.e. enforcement against copyright violations), the quality and reliability of the pirated product, among other factors. For our analysis here we will explicitly take into account of the above mentioned three factors in our model.[11] Analyzing the model, we are able to explain, why sometime pirate(s) operates in the market and the original firm cannot do anything about it; we also show when the original firm will actually be able to stop piracy successfully. All these outcomes come out endogenously in our model of commercial piracy and end-user piracy. We work out the precise conditions when there will be pirate(s) in the market, and when there will be no pirate operating. Our general conclusion is, the pirate(s) survives in the market when the valuation gap is high among the potential software users, enforcement policy against the pirate is weak, and when the pirate(s) produces a software copy that is moderately reliable.

In the forthcoming analysis we just describe the model of retail/commercial piracy and end-user piracy and briefly sketch the results.

The Model of Retail/Commercial Piracy

The Software Firm and the Pirate

Consider an original software firm and a pirate. The pirate has the technology to copy the original software. We assume the pirate produces software copies, which may not be as reliable as the original product. The probability that a pirated software works is q, $q \in (0,1)$ and this probability is common knowledge. Therefore q serves as a proxy for the quality of the pirated software. Usually pirated copies does not come with the supporting services or guarantee, so one can think even if the pirated software is exactly same as the original one (because of digital coping), but the lack of supporting services or guarantee makes it a inferior product compared to the original.

There are two time periods, where in the first period $(t=1)$, the original software developer undertakes costly R&D in order to make piracy costly to the pirate. Costly R&D of the original developer raises the marginal cost of producing a copy by the pirate.[12] The potential pirate appears in the market of the original product in the second time period $(t=2)$. We assume the higher the investment in R&D by the original software developer in the first period, the higher the marginal cost of copying by the pirate. The pirate if survives, competes with the original developer in price by possibly producing less reliable yet cheaper products.

[11] We do acknowledge apart from these factors mentioned here, there are other factors which can influence piracy. But for analytical tractability we restrict ourselves to these factors in this model.

[12] One can imagine when the original firm makes it technologically harder (due to R&D) to copy the product, that would increase one time fixed cost of the pirate, say, to break the security code. However, for simplicity, in this analysis we assume that fixed cost part to be zero. Since it is just a constant, the qualitative results of the analysis remain unaffected without it.

Costs and Profits of the Competing Firms

We assume at $t = 1$, the cost of R&D by the original developer to increase the marginal cost of the pirate by an amount of x is given by $c_O(x) = \frac{x^2}{2}$. Let us call x as the level of deterrence.

Thus, if the profit of the software developer at $t = 2$ is denoted by $\pi_O^2 = p_O D_O$,[13] where p_O is the price charged by the developer and D_O is the demand it faces, then the net profit of the developer at $t = 1$ becomes $\pi_O = \pi_O^2 - c_O(x) = \pi_O^2 - \frac{x^2}{2}$.

On the other hand, if the pirate is in the market at $t = 2$ then its profit function becomes $\pi_P = (p_P - x - c) D_P$, where p_P is the price charged by the pirate and D_P is the pirate's demand and c is a parameter which can be positive or negative and *exogenously*.

c indicates the level of enforcement policy against piracy for a particular environment For example, we will find c to be highly positive 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 find c to be low or even negative, because the enforcement policies against piracy are weak. Hence cost of piracy is either small or in some case the environment is actually conducive to piracy.[14]. It is understood that the local government or the regulatory authority can influence c; however in this analysis we assume it as a parameter.

Consumer Demand

Consider a continuum of consumers indexed by X, $X \in [\theta_L, \theta_H]$, $\theta_H > \theta_L \geq 0$. A consumer's willingness to pay for the software depends on how much he/she values it – measured by X. A high value of X means higher valuation for the software and low value of X means lower valuation for the software. Therefore, one consumer differs from another on the basis of his/her valuation for the particular software. Valuations are uniformly distributed over the interval $[\theta_L, \theta_H]$ and the size of the market is normalized to 1.

A consumer's utility function is given as:

$$U = \begin{cases} X - p_O & \text{if buy original software} \\ qX - p_P \;^{15} & \text{if buy pirated software} \\ 0 & \text{if buy none} \end{cases}$$

[13] Assuming the marginal cost of production of the software is zero for the original firm.

[14] Even if the law against piracy is there, the pirate can get away by offering bribes to the authorities due to widespread corruption in most poor and developing countries which actually encourages piracy.

[15] $qX - p_P = q(X - p_P) + (1-q)(-p_P)$. If the pirated software is not working, consumer does not derive any benefit from the software and instead only incurs a loss equivalent to the amount paid for the pirated software.

There is no way a consumer can get defected pirated software replaced since there is no warranty for the pirated software.[16] Hence, the consumer enjoys the benefit of the pirated software only with probability q. In the event that the pirated software purchased does not work at all, the loss to the consumer is the price paid for it. The original software is fully guaranteed to work. p_O and p_P are the prices of the original and pirated software respectively. It must be true that $p_O > p_P$. $(p_O - p_P)$ can be viewed as the premium a consumer pays for buying "guaranteed-to-work" software.

The Game

In the first period of the game, the original firm invests in R&D, while in the second period if the pirate survives, both firms compete in price. We look for subgame perfect equilibrium of the two period game and solve using the usual method of backward induction.

Results

When the commercial pirate faces a deterrent to operate and stopping piracy is a costly activity to the software firm, the piracy will be stopped when there is some level of enforcement (i.e. c>0, however small) against piracy.

The pirate survives in the market only when the environment is highly conducive to piracy (i.e. c<0, significantly).

The survival of piracy also depends on the valuation gap of the product for the software users and the quality and reliability of the pirated software.

End User Piracy

Under this situation, for simplicity we assume there is no commercial pirate in the economy. The consumers (i.e. all potential software users) are the potential pirates.[17] As before, there is one original software developer (monopoly) and consumers' valuations are uniformly distributed over the interval $[\theta_L, \theta_H]$; $\theta_H > \theta_L \geq 0$ and the size of the market is normalized to 1. Consumers can buy the original product from the monopolist or pirate without paying anything. We assume the probability that a pirated software works is q, $q \in (0,1)$ and this probability is common knowledge. Interpretation of q is same as before. The activity of the original software firm remains exactly the same as before, except that now it targets the end user pirates to stop piracy as opposed to commercial pirate. Unlike the previous case, here it does not face any direct competition

[16] In most markets pirates operate using some makeshift arrangement, if the parted software turns out to be defected, there is no chance of getting software replaced.

[17] 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 present analysis, however, it can be easily verified that there will be no change in the end results (working is available upon request).

from anybody in the market; however, it stands to lose its potential market because of end user piracy. Under this circumstance, it invests in R&D to raise the cost of piracy to the end users.[18] Thus a consumer's utility function is given as:

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

where x is the level of deterrence for piracy and $c > 0$ is the exogenous cost coefficient like before which measures the strictness of enforcement policy against copyright violations.

Result

Qualitatively same as commercial piracy mentioned above.

3. Movie Piracy

Introduction

In recent years, much research and studies have been done on software and music piracy but with little on movie piracy. Movie piracy is difficult compared to music piracy due to the fact that movies files are large and internet connections were slow, and so movie piracy was not considered as rampant or problematic as software and music. However, with rapid technological advances, large capacity digital copying devices, better file compression techniques and broadband connections with downloading speeds unimaginable before are fast becoming the norm. This trend has certainly drawn the attention of movie producers who fear for their work and profits being jeopardized. Hence, in recent months, we see increasing anti-piracy efforts from movie companies and related associations.

The main objective of this paper is to come up with a simple theoretical model of movie piracy and its impact on the box-office (i.e. the movie theatres).[19] This is achieved by recognizing the unique characteristics of movie piracy and gathering intuitions from existing literature of piracy on information goods such as music and software.[20] From the model formulated, we shall assess the impact on prices, demands, profits from the viewpoint of the movie producer and determine the optimal strategy regarding the degree

[18] Here, we do not need the two period time structure as before, everything can be formulated within a single period. A two-period game is also solvable.

[19] In this study we are not looking at the impact of piracy on the original DVD or VCD market for movies. In an article, Chellappa & Shivendu (2002) focus on offline DVD movie piracy. They formulate an analytical model to study the implication of varying technology standards of DVD players across different regions on movie piracy. Fetscherin (2005) presents an empirical paper on pirated movies on peer-to-peer program Kazaa and found that there is a low probability of obtaining high quality movies on Kazza.

[20] To have an understanding on copyright and economic theory and for a comprehensive overview, see Watt (2000).

of restricting piracy. On the consumer side, we will derive the consumer surplus and overall welfare in view of piracy and explain the economic rationale of partial protection or delaying piracy. To the best of our knowledge no theoretical framework has been proposed in the literature to explore a situation like that.[21]

The Rise of Movie Piracy

Piracy of movies started way back since in the 1970s where people stole physical movie prints from lab technicians or projectionists to make pirated copies for distribution.[22] Hence, in today's high-tech society, digital and online movie piracy[23] is an old problem in a new disguise. With the ubiquitous internet and advancing technology, the magnitude of piracy is unprecedented and even on the rise.

Firstly, with the wide availability of large capacity digital copying devices such as CD-writers and DVD-writers, pirating a movie becomes less cumbersome than before. Retail pirates can even make use of these to produce copies at low costs and earn a substantial profit. One can just 'burn' copies of a movie within minutes and distribute to friends. Furthermore, quality of the pirated copies does not deteriorate since digital copying preserves almost everything from the original source. Secondly, we would also expect it to be easier and faster to pirate via the internet. This is illustrated by the fact that more than 50 major movies were illegally copied and released last year even before they came out in theatres, as noted by the Motion Picture Association of America (MPAA). In October 2004, slightly more than 44 million digital files made up of full-length feature films were being shared on peer-to-peer networks, as reported by BigChampagne LLC, which tracks activity on file-sharing networks. Since more files are being shared, it becomes easier to download a pirated movie, and this would have an adverse effect on patronage of movie theatres. Indeed, a survey of 3,600 Internet users in eight countries showed that 17 percent of those downloading movies are buying theatre tickets less often. Most online piracy happens through what is called file-sharing or peer-to-peer (P2P) programs, such as Kazaa, Gnutella and eDonkey, which links millions of computers to one another over the Internet. P2P programs take advantage of the fact that movies can be digitized into data files which can be stored or played on a computer and transmitted over the Internet as easily as sending e-mails. Using these programs, people can literally browse through one another's digital music and movie collections, picking, choosing and swapping whatever they want.[24] Threat also comes from the fast penetrating rate of broadband connections into homes. The worldwide broadband adoption are growing faster grew every year. A high penetration rate would mean that more people are able to share files faster over the internet, thereby increasing the probability of movie piracy. [25]

---

[21] For a comprehensive guide to the movie industry palatable to both the specialist in the movie business and avid reader see Moul (2005).

[22] See TIME magazine archive article, http://www.time.com/time/archive/preview/0,10987,913591,00.html

[23] Online motion picture piracy, as defined by the Motion Picture Association of America (MPAA), is the "*unauthorized use of copyrighted motion pictures on the Internet*". To understand variations in the levels of copyright enforcements among MPAA or firms at the retail level e.g. cable operators see Waterman (2005).

[24] Recently, a new P2P program known as BitTorrent is posing a bigger threat as it allows users to download huge files in a much shorter time. Unlike older file-sharing programs, BitTorrent breaks up large files, such as movies, into small chunks and distribute to many users. This maximizes downloading speeds.

[25] To see more on movie piracy from a sociological perspective, see Yar (2005).

Profitability of a Movie

First of all, movie-making is not always profitable, as affirmed by the MPAA, only two in ten films ever retrieve its investment from domestic exhibition. In fact, four out of ten movies never recoup their original investment. The average major studio film cost over $80 million to produce, inclusive of advertising and marketing. To recoup such enormous investments, the industry relies upon a carefully planned sequential release of movies, first releasing feature films in cinemas, then to home video, and then to other media. This not only provides the best financial return for studios, but also provides consumers with choices as to how and when they wish to view movies. Thus, this carefully planned release sequence, which includes intervals for each specific media known as "distribution windows", are vital to the health of the industry.

With the above, we would expect the crucial period in determining whether a movie is a “box-office hit” to be the first few weeks of its release. Any piracy that is present during the initial release will greatly affect its ticket sales which may cause it to be a “box-office flop” even though it may be a popular pirated or downloaded movie. Given a flop, advertisers and investors may cease their support for releases and promotions in the subsequent “distribution windows”, and a good movie would not even make it to other media.

Consumer’s Valuation of a Movie

Movie is a good example of an “experience good” where consumers must test and enjoy the good personally to value it. Therefore, valuation of a movie is very much dependent on each individual’s preferences and tastes. We then expect consumers to be distributed between high valuation and low valuation. Cost of watching a movie in theatre is the price of the movie ticket. Pirated movie will have some differences in quality as compared to the original theatre movie. It could be due to poorer visual and audio quality, or simply because the ambience at home is different from the cinema. As a consequence, there will be some discount factor when one watches a pirated movie. This is because pirated movie may be a close substitute but never a perfect substitute of movie watched in theatre. The cost of copying or downloading an additional movie is close to zero since one has the necessary hardware; the only cost is the time spent searching and downloading.

When we watch movies in theatres, buying a ticket only entitles us to a one-time “consumption” of the movie and there is no way for repeat usage without paying for another ticket. This is unlike the case of buying a music or software CD, where an individual can have repeat usage from one purchase. Repeat usage is very common in software and music, be it original or pirated copy. This is because one needs to use a software or music repeatedly to bring out the full value in them, and one can derive new utility from every repeated use. However, in the case of theatre or pirated movie, one is not expected to watch the same movie repeatedly. The full value or utility of a movie is obtained from the first time you watch it, hence with little need for repeat viewing.

The plan of the paper is as follows. In the next section, we provide a simple model to study the implications of movie piracy on movies shown in the theatres. In section 3, we will consider three scenarios in turn. In the first scenario, we assume that there is no scope for piracy and the movie market is fully protected. This is our benchmark case. In the second scenario, we consider the other extreme and assume that there is no form of protection at all and pirated movies are available from the very beginning of a new movie release. In the third scenario, we consider the case of partial protection which is actually mostly observed in reality. Here we assume the pirated versions of a movie is not available at the time of its release, however, it is available at later point of time. After analyzing these three scenarios, in section 4, we study the impact of piracy on the demands, prices and profits of the movie company and rank the profits of the movie company from all three scenarios.[26] A simple welfare analysis is done in section 5 followed by a discussion of a 'desired policy' with respect to allowing movie piracy that balances the interest of movie producer and consumers. Section 6 concludes.

The Model

The model considers a simplified market with one original movie company[27]. The film is released in movie theatres and shown for two periods, where specifically the first period is when the movie is classified as a "new release". The company set prices to maximize its profit over the two periods. On the demand side, we assume a continuum of consumers indexed by *X,* $X \in [\theta_L, \theta_H]$, where $\theta_H > \theta_L \geq 0$. The value of *X* measures a consumer's valuation for the particular movie and his willingness to buy a ticket. Consumer's valuations are heterogeneous and we assume *X* to be uniformly distributed over the interval $[\theta_L, \theta_H]$ where the size of the market is normalized to 1.

Consumers have three basic choices regarding the way to watch the movie: watch the original movie in the first or second period in movie theatre; watch the pirated version whenever it is available without incurring any unitary cost; or choose not watch at all. The marginal cost of piracy is zero as we assume consumers have the technology to copy or download the movie at negligible cost. We do not assume repeat viewing in this model. Watching a movie is a one-time affair and hence the corresponding utility gain. Those who watched in the first period, be it original or pirated version, will not watch again in the second period.

A consumer enjoys a utility of *X* for watching the original movie in the first period and a utility of δX if he watches in the second period, where $\delta \in (0,1)$. δ is the discount factor to account for the loss in utility when postponing the viewing of the movie to the second period. This may come from the fact that the hype or novelty of a movie is lost if watched in the second period where it is no longer considered a "new release".[28] If a consumer watches a pirated version in the first period, he derives a utility of *qX*, and δqX if he does it in the second period, where $q \in (0,1)$[29]. This is because there is a quality difference between the original and the pirated movie (e.g. poor audio and visual effects, or simply because of the lack of ambience as in the theatres). A higher

---

[26] In this framework for our purpose, we do not distinguish between movie producers and theatre owners as the main objective of both these agents is same i.e. to generate maximum profit from a new movie.

[27] The movie company will incur costs, possibly big, during the production of the movie but this will be considered sunk once it is ready for release. The cost of duplicating the film for distribution is assumed to be negligible.

[28] The value of δ could measure the degree of impatience of the individual. A lower δ means a more impatient individual since he discounts future consumption heavily.

[29] Although we assume that the cost of piracy is zero, other costs such as the time spent on searching, copying and downloading may be factored into *q*, where it will simply bring down the overall utility of watching a pirated version.

q signifies a higher quality product but will be bounded away from 1 since it will never be a perfect substitute for the theatre movie. We summarize a consumer's one-period utility function as follows:

$$U_t = \begin{cases} \delta^{t-1}X - P_t & \text{if he watches movie in theatre in period } t \\ \delta^{t-1}qX & \text{if he watches pirated movie in period } t \\ 0 & \text{if he does not watch} \end{cases}$$

We shall now proceed to consider the three scenarios: first, when there is full protection of original movies and piracy is non-existent; second, when there is no protection so the pirated version is available from period 1; lastly, when there is some form of protection to deter piracy so that pirated version is only available in the second period and thus only original movie is available in the first period.

Analysis

Full Protection (No movie piracy exists)

In this scenario, movies are fully protected against any forms of piracy. This may be achieved through efforts such as developing advanced techniques to restrict digital and online piracy, stringent monitoring of piracy activities and stricter copyright enforcement laws. With the absence of piracy, a consumer is limited to three choices: watch movie in the theatre in first period; watch in the theatre in second period; or not watching it at all. The consumer's overall utility is defined as below:

$$U = \begin{cases} X - P_{NP,\,1} & \text{if he watches theatre movie in first period} \\ \delta X - P_{NP,\,2} & \text{if he watches theatre movie in second period} \\ 0 & \text{if he does not watch at all} \end{cases}$$

where the subscript *NP* denotes the case with no piracy and the number denotes the period.

With the market size held static, consumers who chose not to watch in the first period may watch in the second period. The marginal consumer X_1, who is indifferent between watching in the first period and watching it in the second period, is given by:[30]

$$X_1 - P_{NP,1} = \delta X_1 - P_{NP,2}$$

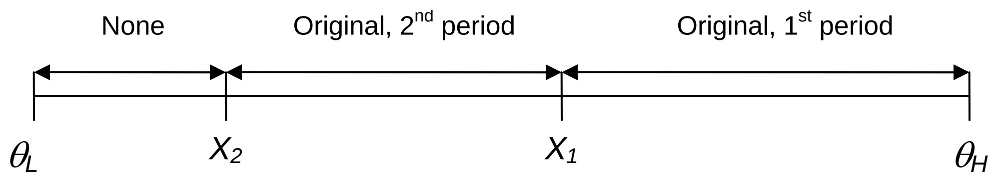
$$X_1 = \frac{P_{NP,1} - P_{NP,2}}{1-\delta}$$

The marginal consumer X_2, who is indifferent between watching the movie in theatre in second period and not watching any, is given by:

[30] Ticket price is assumed to be different in both periods. This is because when a film is a "new release", there is always a "no free list" condition such that discounts or complimentary coupons cannot be used. In Singapore, for instance, it cost more to watch on the day when a movie is just released compared to the same day a week later.

$$\delta X_2 - P_{NP,2} = 0$$
$$X_2 = \frac{P_{NP,2}}{\delta}$$

Figure 1: DISTRIBUTION OF CONSUMERS (NO PIRACY)



Demand for movie in the first period, $D_{NP,1}$ is:

$$D_{NP,1} = \int_{X_1}^{\theta_H} \frac{1}{\theta_H - \theta_L} dx = \frac{\theta_H(1-\delta) - (P_{NP,1} - P_{NP,2})}{(\theta_H - \theta_L)(1-\delta)}$$

Since we assume zero marginal costs, movie producer's profit in first period, $\pi_{NP,1}$ is:

$$\pi_{NP,1} = P_{NP,1} \cdot D_{NP,1} = P_{NP,1} \cdot \frac{\theta_H(1-\delta) - (P_{NP,1} - P_{NP,2})}{(\theta_H - \theta_L)(1-\delta)}$$

Demand for movie in second period, $D_{NP,2}$ is:

$$D_{NP,2} = \int_{X_2}^{X_1} \frac{1}{\theta_H - \theta_L} dx = \frac{\delta(P_{NP,1} - P_{NP,2}) - P_{NP,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta)}$$

Movie producer's profit in second period $\pi_{NP,2}$ is:

$$\pi_{NP,2} = P_{NP,2} \cdot D_{NP,2} = P_{NP,2} \cdot \frac{\delta(P_{NP,1} - P_{NP,2}) - P_{NP,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta)}$$

Using backward induction to solve the producer's profit maximization problem, starting from the second period, the firm set price $P_{NP,2}$, such that:

$$\frac{\partial \pi_{NP,2}}{\partial P_{NP,2}} = \frac{\delta(P_{NP,1} - 2P_{NP,2}) - 2P_{NP,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta)} = 0$$

Solving, we obtain the second period's price as a function of the first-period price:

$$\therefore P_{NP,2}(P_{NP,1}) = \frac{\delta P_{NP,1}}{2}$$

Substituting into demand and profits functions, we can express them in terms of $P_{NP,1}$ to get:

$$D_{NP,1}(P_{NP,1}) = \frac{2\theta_H(1-\delta) - (2-\delta)P_{NP,1}}{2(\theta_H - \theta_L)(1-\delta)};$$

$$\pi_{NP,1}(P_{NP,1}) = P_{NP,1} \cdot \frac{2\theta_H(1-\delta)-(2-\delta)P_{NP,1}}{2(\theta_H-\theta_L)(1-\delta)};$$

$$D_{NP,2}(P_{NP,1}) = \frac{P_{NP,1}}{2(\theta_H-\theta_L)(1-\delta)};$$

$$\pi_{NP,2}(P_{NP,1}) = \frac{\delta P^2_{NP,1}}{4(\theta_H-\theta_L)(1-\delta)}$$

The total profits for both periods, π_{NP} is given by:

$$\pi_{NP}(P_{NP,1}) = \pi_{NP,1} + \pi_{NP,2} = \left[P_{NP,1} \cdot \frac{2\theta_H(1-\delta)-(2-\delta)P_{NP,1}}{2(\theta_H-\theta_L)(1-\delta)}\right] + \left[\frac{\delta P^2_{NP,1}}{4(\theta_H-\theta_L)(1-\delta)}\right]$$

Movie producer will maximize profit with respect to first period price such that:

$$\frac{\partial \pi_{NP}}{\partial P_{NP,1}} = \frac{2\theta_H(1-\delta)-(4-3\delta)P_{NP,1}}{2(\theta_H-\theta_L)(1-\delta)} = 0$$

Solving, we get the profit-maximizing prices:

$$P^*_{NP,1} = \frac{2\theta_H(1-\delta)}{4-3\delta}; \tag{1}$$

$$P^*_{NP,2} = \frac{\delta\theta_H(1-\delta)}{4-3\delta} \tag{2}$$

The equilibrium demands of the first and second period are:

$$D^*_{NP,1} = \frac{2\theta_H(1-\delta)}{(\theta_H-\theta_L)(4-3\delta)}; \tag{3}$$

$$D^*_{NP,2} = \frac{\theta_H}{(\theta_H-\theta_L)(4-3\delta)} \tag{4}$$

Total demand for movie shown in theater is hence:

$$D^*_{NP} = D^*_{NP,1} + D^*_{NP,2} = \frac{\theta_H(3-\delta)}{(\theta_H-\theta_L)(4-3\delta)} \tag{5}$$

Therefore, movie producer's profit is:

$$\pi^*_{NP} = \frac{\theta_H^2(1-\delta)}{(\theta_H-\theta_L)(4-3\delta)} \tag{6}$$

From equation (1) and (2), we can verify that $P^*_{NP,1} > P^*_{NP,2}$ for all values of δ and $D^*_{NP,1} > D^*_{NP,2} \Leftrightarrow \delta < 0.5$. It is evident from equilibrium demands that if consumers are generally impatient there will be more demand in period 1.

No Protection (Piracy exists from first period)

This scenario is where there is no protection against illicit piracy. Under this scenario, pirated versions will be available from period 1, on par with the release of the original movie[31]. The movie producer maximizes his profits, taking into account demands lost to

[31]Some actual examples include movies like "The Hulk" and "Star Wars: Episode2" where full length versions were made available on peer-to-peer programs days before the actual release of the movies.

piracy. A consumer whose valuation is such that he watches the pirated version will do it in the first period, as there is no incentive to postpone with a discount factor in the second period. A consumer now has these choices: watch movie in the theatre in first period; watch in the theatre in second period; watch the pirated movie in the first period where it is available. Hence, a consumer's overall utility is:

$$U = \begin{cases} X - P_{P^1,1} & \text{if he watches movie in theatre in first period} \\ \delta X - P_{P^1,2} & \text{if he watches movie in theatre in second period} \\ qX & \text{if he watches pirated movie in first period} \end{cases}$$

where the subscript P^1 denotes the case with piracy from first period.

The marginal consumer X_1, who is indifferent between watching the movie in theatre in the first period and watching it in the second period, is given by:

$$X_1 - P_{P^1,1} = \delta X_1 - P_{P^1,2}$$

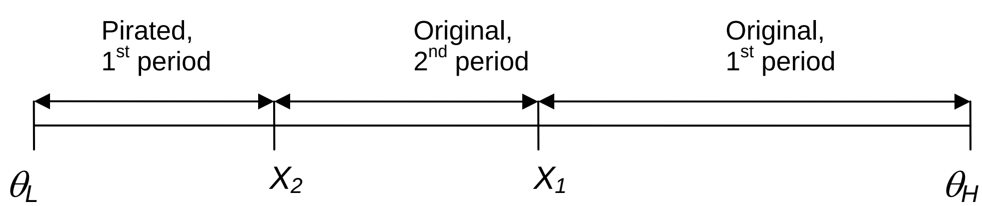
$$\therefore X_1 = \frac{P_{P^1,1} - P_{P^1,2}}{1-\delta}$$

The marginal consumer X_2 , who is indifferent between watching the movie in theatre in the second period and watching the pirated version in first period, is given by:

$$\delta X_2 - P_{P^1,2} = qX_2$$

$$\therefore X_2 = \frac{P_{P^1,2}}{\delta - q}$$

Figure 2: DISTRIBUTION OF CONSUMERS (PIRACY EXISTS FROM THE FIRST PERIOD), $\delta > q$



Demand for theatre movie in the first period $D_{P^1,1}$ is:

$$D_{P^1,1} = \int_{X_1}^{\theta_H} \frac{1}{\theta_H - \theta_L} dx = \frac{\theta_H (1-\delta) - \left(P_{P^1,1} - P_{P^1,2}\right)}{(\theta_H - \theta_L)(1-\delta)}$$

Movie producer's profit in first period $\pi_{P^1,1}$ is:

$$\pi_{P^1,1} = P_{P^1,1} \cdot D_{P^1,1} = P_{P^1,1} \cdot \frac{\theta_H (1-\delta) - \left(P_{P^1,1} - P_{P^1,2}\right)}{(\theta_H - \theta_L)(1-\delta)}$$

Demand for movie in second period, $D_{P^1,2}$ is:

$$D_{P^1,2} = \int_{x_2}^{x_1} \frac{1}{\theta_H - \theta_L} dx = \frac{(\delta - q)\left(P_{P^1,1} - P_{P^1,2}\right) - P_{P^1,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta - q)}$$

Movie producer's profit in second period $\pi_{P^1,2}$ is:

$$\pi_{P^1,2} = P_{P^1,2} \cdot D_{P^1,2} = P_{P^1,2} \cdot \frac{(\delta - q)\left(P_{P^1,1} - P_{P^1,2}\right) - P_{P^1,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta - q)}$$

Same as before, we use backward induction to solve the producer's profit maximization problem, starting from the second period, the firm set price $P_{P^1,2}$, such that:

$$\frac{\partial \pi_{P^1,2}}{\partial P_{P^1,2}} = \frac{(\delta - q)\left(P_{P^1,1} - 2P_{P^1,2}\right) - 2P_{P^1,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta - q)} = 0$$

Solving, we obtain the second period's price as a function of the first-period price:

$$\therefore P_{P^1,2}(P_{P^1,1}) = \frac{P_{P^1,1}(\delta - q)}{2(1-q)}$$

Substituting into the demand and profit functions, we can express them in terms of $P_{P^1,1}$ to get:

$$D_{P^1,1}(P_{P^1,1}) = \frac{2\theta_H(1-q)(1-\delta) - (2-\delta-q)P_{P^1,1}}{2(\theta_H - \theta_L)(1-\delta)(1-q)};$$

$$\pi_{P^1,1}(P_{P^1,1}) = P_{P^1,1} \cdot \frac{2\theta_H(1-q)(1-\delta) - (2-\delta-q)P_{P^1,1}}{2(\theta_H - \theta_L)(1-\delta)(1-q)};$$

$$D_{P^1,2}(P_{P^1,1}) = \frac{P_{P^1,1}}{2(\theta_H - \theta_L)(1-\delta)};$$

$$\pi_{P^1,2}(P_{P^1,1}) = \frac{(\delta - q)P^2_{P^1,1}}{4(\theta_H - \theta_L)(1-\delta)(1-q)}$$

Total profits for both periods, π_{P^1}, is given by:

$$\begin{aligned}\pi_{P^1}(P_{P^1,1}) &= \pi_{P^1,1} + \pi_{P^1,2} \\ &= \left[P_{P^1,1} \cdot \frac{2\theta_H(1-q)(1-\delta) - (2-\delta-q)P_{P^1,1}}{2(\theta_H - \theta_L)(1-\delta)(1-q)}\right] + \left[\frac{(\delta - q)P^2_{P^1,1}}{4(\theta_H - \theta_L)(1-\delta)(1-q)}\right]\end{aligned}$$

Maximizing total profits with respect to first period price such that:

$$\frac{\partial \pi_{P^1}}{\partial P_{P^1,1}} = \frac{2\theta_H(1-q)(1-\delta) - (4-q-3\delta)P_{P^1,1}}{2(\theta_H - \theta_L)(1-\delta)(1-q)} = 0$$

Solving, we get the profit-maximizing prices and equilibrium demands:

$$P^*_{P^1,1} = \frac{2\theta_H(1-q)(1-\delta)}{4-q-3\delta}; \qquad (7)$$

$$P^*_{P^1,2} = \frac{\theta_H(\delta - q)(1-\delta)}{4 - q - 3\delta} \quad (8)$$

$$D^*_{P^1,1} = \frac{2\theta_H(1-\delta)}{(\theta_H - \theta_L)(4 - q - 3\delta)}; \quad (9)$$

$$D^*_{P^1,2} = \frac{\theta_H(1-q)}{(\theta_H - \theta_L)(4 - q - 3\delta)} \quad (10)$$

Total demand for movies in theatre is hence:

$$D^*_{P^1} = D^*_{P^1,1} + D^*_{P^1,2} = \frac{\theta_H(3 - 2\delta - q)}{(\theta_H - \theta_L)(4 - q - 3\delta)} \quad (11)$$

Therefore, movie producer's profit is:

$$\pi^*_{P^1} = \frac{\theta_H^2(1-q)(1-\delta)}{(\theta_H - \theta_L)(4 - q - 3\delta)} \quad (12)$$

It can be observed from equation (7) and (8) that $P^*_{P^1,1} > P^*_{P^1,2}$ for all values of δ. Also, $D^*_{P^1,1} > D^*_{P^1,2} \Leftrightarrow \delta < 0.5(1-q)$. In addition, looking at equation (8), we need to assume that $\delta > q$, to ensure that positive prices and demand exists in the second period.

The analysis for the other case follows.

Case of $q > \delta$

Now, we consider the case when $q > \delta$. When that happens, there is no second period demand. Thus in the first period, consumer either watch the original movie or watch the pirated version. The utility function will be as follows:

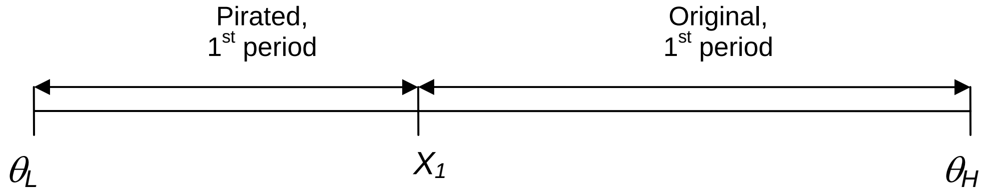
$$U = \begin{cases} X - P_{P^1,q>\delta} & \text{, if he watches the movie in theatre} \\ qX & \text{, if he watches the pirated version} \end{cases}$$

The marginal consumer, X_1, who is indifferent in watching original or pirated version is:

$$X_1 - P_{P^1,q>\delta} = qX_1$$

$$X_1 = \frac{P_{P^1,q>\delta}}{1-q}$$

Figure 3: DISTRIBUTION OF CONSUMERS (PIRACY EXISTS FROM THE FIRST PERIOD), $q > \delta$



Demand of theatre movie is:

$$D_{P^1,q>\delta} = \int_{X_1}^{\theta_H} \frac{1}{\theta_H - \theta_L} dx = \frac{\theta_H(1-q) - P_{P^1,q>\delta}}{(\theta_H - \theta_L)(1-q)}$$

Profit of the movie producer is given by:

$$\pi_{P^1,q>\delta} = P_{P^1,q>\delta} \cdot D_{P^1,q>\delta} = P_{P^1,q>\delta} \cdot \frac{\theta_H(1-q) - P_{P^1,q>\delta}}{(\theta_H - \theta_L)(1-q)}$$

Maximizing the profit with respect to price, such that:

$$\frac{\partial \pi_{P^1,q>\delta}}{\partial P_{P^1,q>\delta}} = \frac{\theta_H(1-q) - 2P_{P^1,q>\delta}}{(\theta_H - \theta_L)(1-q)} = 0$$

Solving, we can get the profit maximizing price, $P^*_{P^1,q>\delta}$ and equilibrium demand, $D^*_{P^1,q>\delta}$:

$$P^*_{P^1,q>\delta} = \frac{\theta_H(1-q)}{2} \tag{13}$$

$$D^*_{P^1,q>\delta} = \frac{\theta_H}{2(\theta_H - \theta_L)} \tag{14}$$

The producer's profit is hence:

$$\pi^*_{P^1,q>\delta} = \frac{\theta_H^{\ 2}(1-q)}{4(\theta_H - \theta_L)} \tag{15}$$

Partial Protection (Piracy exists only in the second period)

In this third scenario, there is some degree of protection but not enough to eliminate piracy completely. Any form of piracy in the first period will greatly affect its profitability and so the movie company will try all means to prevent piracy, even if they cannot stop piracy in subsequent periods. As such, piracy will now be "delayed"; pirated version will only be available in the second period and consumers only have the options of watching movie in theatre in the first period. A consumer can choose to: watch move in the theatre movie in first period; watch in the theatre in second period; download the pirated version in second period. His overall utility function is given as follows:

$$U = \begin{cases} X - P_{P^2,1} & \text{if he watches movie in theatre in first period} \\ \delta X - P_{P^2,2} & \text{if he watches movie in theatre in second period} \\ \delta q X & \text{if he watches pirated movie in first period} \end{cases}$$

The marginal consumer X_1, who is indifferent between watching the movie in theatre in the first period and watching it in the second period, is given by:

$$X_1 - P_{P^2,1} = \delta X_1 - P_{P^2,2}$$

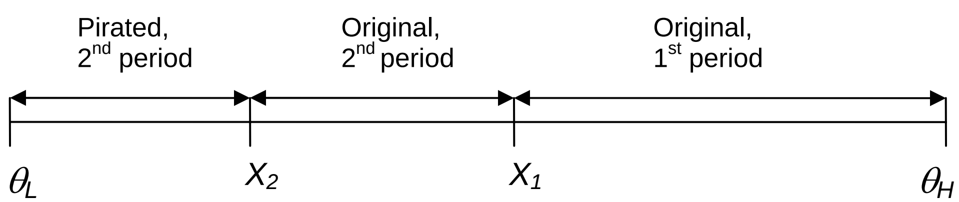
$$\therefore X_1 = \frac{P_{P^2,1} - P_{P^2,2}}{1-\delta}$$

The marginal consumer X_2 , who is indifferent between watching the movie in theatre in the second period and watching the pirated version in first period, is given by:

$$\delta X_2 - P_{P^2,2} = \delta q X_2$$

$$\therefore X_2 = \frac{P_{P^2,2}}{\delta - \delta q}$$

Figure 4: DISTRIBUTION OF CONSUMERS (PIRACY EXISTS ONLY IN THE SECOND PERIOD)



Demand for movie in the first period, $D_{P^2,1}$ is:

$$D_{P^2,1} = \int_{X_1}^{\theta_H} \frac{1}{\theta_H - \theta_L} dx = \frac{\theta_H (1-\delta) - \left(P_{P^2,1} - P_{P^2,2}\right)}{(\theta_H - \theta_L)(1-\delta)}$$

Movie producer's profit in first period $\pi_{P^2,1}$ is:

$$\pi_{P^2,1} = P_{P^2,1} \cdot D_{P^2,1} = P_{P^2,1} \cdot \frac{\theta_H (1-\delta) - \left(P_{P^2,1} - P_{P^2,2}\right)}{(\theta_H - \theta_L)(1-\delta)}$$

Similarly, demand $D_{P^2,2}$ and profit $\pi_{P^2,2}$ for the second period, are:

$$D_{P^2,2} = \int_{X_2}^{X_1} \frac{1}{\theta_H - \theta_L} dx = \frac{(\delta - \delta q)\left(P_{P^2,1} - P_{P^2,2}\right) - P_{P^2,2}(1-\delta)}{(\theta_H - \theta_L)(1-\delta)(\delta - \delta q)}$$

$$\pi_{P^2,2} = P_{P^2,2} \cdot D_{P^2,2} = P_{P^2,2} \cdot \frac{(\delta - \delta q)\left(P_{P^2,1} - P_{P^2,2}\right) - P_{P^2,2}(1-\delta)}{\left(\theta_H - \theta_L\right)(1-\delta)\left(\delta - \delta q\right)}$$

Once again using backward induction, we maximize $\pi_{P^2,2}$ with respect to $P_{P^2,2}$ and obtain the second period's price as a function of the first-period price:

$$P_{P^2,2}(P_{P^2,1}) = \frac{P_{P^2,1}(\delta - \delta q)}{2(1-\delta q)}$$

Substituting into the demand and profit functions, we can express them in terms of $P_{P^2,1}$ to get:

$$D_{P^2,1}(P_{P^2,1}) = \frac{2\theta_H(1-\delta q)(1-\delta) - (2-\delta-\delta q)P_{P^2,1}}{2\left(\theta_H - \theta_L\right)(1-\delta)(1-\delta q)};$$

$$\pi_{P^2,1}(P_{P^2,1}) = P_{P^2,1} \cdot \frac{2\theta_H(1-\delta q)(1-\delta) - (2-\delta-\delta q)P_{P^2,1}}{2\left(\theta_H - \theta_L\right)(1-\delta)(1-\delta q)};$$

$$D_{P^2,2}(P_{P^2,1}) = \frac{P_{P^2,1}}{2\left(\theta_H - \theta_L\right)(1-\delta)};$$

$$\pi_{P^2,2}(P_{P^2,1}) = \frac{(\delta - \delta q)P^2_{P^2,1}}{4\left(\theta_H - \theta_L\right)(1-\delta)(1-\delta q)}$$

Total profits for both periods, π_{P^2} is given by:

$$\pi_{P^2}(P_{P^2,1}) = \pi_{P^2,1} + \pi_{P^2,2}$$

$$= \left[P_{P^2,1} \cdot \frac{2\theta_H(1-\delta q)(1-\delta) - (2-\delta-\delta q)P_{P^2,1}}{2\left(\theta_H - \theta_L\right)(1-\delta)(1-\delta q)}\right] + \left[\frac{(\delta - \delta q)P^2_{P^2,1}}{4\left(\theta_H - \theta_L\right)(1-\delta)(1-\delta q)}\right]$$

Again, movie producer will maximize total profits with respect to $P_{P^2,1}$ such that:

$$\frac{\partial \pi_{P^2}}{\partial P_{P^2,1}} = \frac{2\theta_H(1-\delta q)(1-\delta) - (4-\delta q-3\delta)P_{P^2,1}}{2(\theta_H - \theta_L)(1-\delta)(1-\delta q)} = 0$$

Solving, we get the profit-maximizing prices and demands:

$$P^*_{P^2,1} = \frac{2\theta_H(1-\delta q)(1-\delta)}{4-\delta q-3\delta}; \tag{16}$$

$$P^*_{P^2,2} = \frac{\theta_H(\delta - \delta q)(1-\delta)}{4-\delta q-3\delta} \tag{17}$$

$$D^*_{P^2,1} = \frac{2\theta_H(1-\delta)}{(\theta_H - \theta_L)(4-\delta q-3\delta)}; \tag{18}$$

$$D^*_{P^2,2} = \frac{\theta_H(1-\delta q)}{(\theta_H - \theta_L)(4-\delta q-3\delta)} \tag{19}$$

Total legitimate demand and equilibrium profit is hence:

$$D^*_{P^2} = D^*_{P^2,1} + D^*_{P^2,2} = \frac{\theta_H(3-2\delta-\delta q)}{(\theta_H - \theta_L)(4-\delta q-3\delta)} \tag{20}$$

$$\pi^*_{P^2} = \frac{\theta_H{}^2(1-\delta q)(1-\delta)}{(\theta_H-\theta_L)(4-\delta q-3\delta)} \quad (21)$$

From equation (16) and (17), note that $P^*_{P^2,1} > P^*_{P^2,2}$ for all values of δ and $D^*_{P^2,1} > D^*_{P^2,2} \Leftrightarrow \delta < \frac{1}{2-q}$. Note that when $q = 0$ this is equivalent of non-existence of piracy as pirated version is not reliable at all.

Results

Comparative Statics

Table 1: COMPARATIVE STATICS (PRICE)

	Partial Derivatives	
	δ	***q***
1st period: $(P^*_{NP,1}, P^*_{P^1,1}, P^*_{P^1,q>\delta}, P^*_{P^2,1})$	(-, -, **0**, -)	(**0**, -, -, -)
2nd period: $(P^*_{NP,2}, P^*_{P^1,2}, P^*_{P^2,2})$	(+, +, +)	(**0**, -, -)

Table 2: COMPARATIVE STATICS (DEMAND AND PROFIT)

		Partial Derivatives	
		δ	***q***
1st period:	$(D^*_{NP,1} D^*_{P^1,1}, D^*_{P^2,1})$ [32]	(-, -, -)	(**0**, +, +)
2nd period:	$(D^*_{NP,2}, D^*_{P^1,2}, D^*_{P^2,2})$	(+, +, +)	(**0,** -, -)
Total Demand:	$(D^*_{NP}, D^*_{P^1}, D^*_{P^1,q>\delta}, D^*_{P^2})$	(+, +, **0**, +)	(**0,** -, **0**, -)
Total Profit:	$(\pi^*_{NP}, \pi^*_{P^1}, \pi^*_{P^1,q>\delta}, \pi^*_{P^2})$	(-, -, **0**, -)	(-, -, -, -)

Below we summarize the results in the Table.

Lemma 1

When there is piracy, either from the first or second period, prices of movie tickets in both periods are decreasing in the quality of the pirated movie.

Proof: Follows from Table 1.

Lemma 2

Total legitimate demand of movie tickets and profit of producer are non-increasing in the quality of the pirated movie in the presence of any piracy.

Proof: Follows from Table 2.

---

[32] Note that the comparative static for $D^*_{P^1,1}$ is true only when δ>q. When q>δ, demand is independent of q.

Results in Lemma 1 and 2 are straight forward as good quality pirated movie provides a stiffer competition to the movie company.

Lemma 3

For all scenarios, first period prices and demands are decreasing in δ while for the second period they are increasing in δ.

Proof: Follows from Table 1 and 2.

When individuals are impatient and discount the future periods more, δ becomes smaller. Lemma 3 says when individuals are impatient, more will want to watch in the first period instead, and vice-versa.

Lemma 4

For all scenarios, total profits are decreasing in δ.

Proof: Follows from Table 2.

This suggests that when individuals are impatient and want to watch as soon as possible, producers can set higher prices to capture their higher valuation, thus increasing profits.

Effect of Piracy on First Period Demand

Proposition 1

In comparing legitimate demand in the first period among all the scenarios, the scenario where piracy exists from the first period will have the highest first period demand as compared to the other two scenarios.[33]

Proof: From (3), (9) and (18), observe that their numerators are the same. Their denominators are such that $(4-q-3\delta)<(4-q\delta-3\delta)<(4-3\delta)$. Since $D^{*}_{P^1,1}$ has the smallest denominator, it follows that it has the highest demand.

Table 2 shows that first period demand is increasing in ***q*** while second period and total demand is decreasing in ***q***. This leads to the above proposition where it suggests that first period demand increases with the degree of piracy. This result may seem counter intuitive; however, note that this increase is at the expense of producer's profits. We know that when there is increased piracy or when ***q*** increases, producers need to slash prices. When prices are lowered, those marginal consumers who were indifferent between watching in the first or second period will now watch in the first period as prices are lower. As ***q*** or piracy keeps increasing, producer needs to continue lowering prices and more marginal consumers will switch to watching in the first period, thereby increasing first period demand and hence explaining the positive relationship with ***q***. At the same time, second period's prices and demand are falling and this constitutes loss in profits even thought first period demand is increasing. It can be observed that the total demand, on the other hand, is the smallest in the second scenario and highest in the first scenario. This is because the increase in period one demand is less than the decrease in period two demand. We can also say that the elasticity of watching pirated version is higher than the elasticity of watching original movie in the first period.

[33] It can be proven that both cases under the second scenario holds this proposition true. Here, we use the first case where q<δ.

Main Result
Proposition 2

The ranking of the profits of the movie producer from all three scenarios is as follows: $\pi^*_{NP} > \pi^*_{P^2} > \pi^*_{P^1}$.

Proof: From equation (6) and (21), we get the producer's total profits for each case. We can find that $\pi^*_{NP} - \pi^*_{P^2} = \dfrac{\theta^2_H(1-\delta)^2 3\delta q}{(\theta_H - \theta_L)(4-3\delta)(4-\delta q - 3\delta)}$. This is always positive since $\theta_H > \theta_L \geq 0$, $\delta \in (0,1)$ and $q \in (0,1)$. Therefore $\pi^*_{NP} > \pi^*_{P^2}$.

Observe from (12) and (21), $\pi^*_{P^2} - \pi^*_{P^1} = \dfrac{\theta^2_H(1-\delta)^3 3q}{(\theta_H - \theta_L)(4-q-3\delta)(4-\delta q - 3\delta)}$.

Because $\theta_H > \theta_L \geq 0$, $\delta \in (0,1)$ and $q \in (0,1)$, this expression is always positive. Therefore $\pi^*_{P^2} > \pi^*_{P^1}$. Hence overall, $\pi^*_{NP} > \pi^*_{P^2} > \pi^*_{P^1}$. [34]

It is not hard to understand that it is always an optimal strategy for the movie producers to deter piracy. Even when the ideal scenario of no piracy is not attainable, it is profitable for the movie producer to delay the piracy at least. When piracy exists, the movie producer is no longer the sole distributor and thus is unable to appropriate the additional consumer surplus through setting higher prices, so they earn lesser profits. It can also be observed from Table 2 that profits are decreasing in ***q***. This means that when the quality of the pirated version increases, consumers have more incentive to switch, hence reducing profits.

Other reason for the decreased profits is the impact on prices in view of piracy. It can be verified that prices are the lowest in the second scenario (i.e. piracy from period one) where there is no protection against piracy. Movie piracy could be seen as a form of competition to the movie producers since it steals from legitimate demand. Thus, faced with a lower demand, movie producers have no choice but cut prices to win back consumers. Table 1 shows that ticket prices are decreasing in ***q***. Hence as ***q*** increases, producers need to cut prices more to retain consumers whose incentive to switch to pirated version increases. In addition, for all three scenarios, ticket prices in the first period are higher than the second period. This is because producers know that those who choose to watch in the first period have higher valuation, thus they can set a higher price to capture their surplus. Note also that from the equilibrium prices derived, there is a factor of θ_H in all of them. This shows that producer set prices with reference to high-valuation consumers and not low-valuation ones. The above analysis is true for the second case only when $\delta > q$.

If $\delta < q$, we have the results in previous sections. When ***q*** becomes very large, price of original movie will drop sharply. It then makes not much difference to the consumer to watch the original or pirated version since the utility gained is almost the same for both. Therefore, from (14), we see that demand do not depends on ***q***. Price and profit, same as before, decrease with ***q***.

[34] Here, we use profit from the case of δ>q in the scenario where piracy exist from the first period. However, it can be checked that the proposition still hold in the other case of q<δ.

Consumer Surplus and Social Welfare

We have seen how movie piracy shrinks producers' profits. In their viewpoint, it is most profitable to eliminate piracy totally. However, this may not be realistically possible; and we will also show that it may not be the best outcome for the society as a whole. Piracy merely means more choices to consumers and increase in competition which drive prices down, and benefits consumers. This benefit is measured by the consumer surplus. Consumer surplus in watching a movie is *X* and the expenditure is just the price of ticket, *P*. We find the consumer's surplus for all three scenarios described earlier. Total social welfare will then be derived by adding consumer's surplus and equilibrium profits of the movie producer. This would enable us to have an overall welfare effect on the economy in the presence of piracy. For computation simplicity, we will use $\theta_H = 1$ and $\theta_L = 0$.

Full Protection (No movie piracy exists)

When $\theta_H = 1$ and $\theta_L = 0$, prices in first and second period, and equilibrium profit are:

$$P^*_{NP,1} = \frac{2(1-\delta)}{4-3\delta};$$

$$P^*_{NP,2} = \frac{\delta(1-\delta)}{4-3\delta};$$

$$\pi^*_{NP} = \frac{(1-\delta)}{(4-3\delta)}$$

Hence substituting prices, we can get the marginal consumer X_1 and X_2:

$$X_1 = \frac{P_1 - P_2}{1-\delta} = \frac{2-\delta}{4-3\delta}; \qquad X_2 = \frac{P_2}{\delta} = \frac{1-\delta}{4-3\delta}$$

Consumer surplus, CS_{NP} is derived as follows:

$$CS_{NP} = \int_{X_1}^{1} (X - P_{NP,1})dx + \int_{X_2}^{X_1} (\delta X - P_{NP,2})dx = \left[\frac{X^2}{2} - XP_{NP,1}\right]_{X_1}^{1} + \left[\frac{\delta X^2}{2} - XP_{NP,2}\right]_{X_2}^{X_1}$$

Substituting in the variables, we get:

$$CS^*_{NP} = \frac{4-4\delta}{2(4-3\delta)^2} + \frac{\delta}{2(4-3\delta)^2} = \frac{1}{2(4-3\delta)} \tag{22}$$

Total welfare, W^*_{NP} is therefore:

$$W^*_{NP} = CS^*_{NP} + \pi^*_{NP} = \frac{3-2\delta}{2(4-3\delta)} \tag{23}$$

No Protection (Piracy exists from first period)

Case when $\delta > q$

When $\theta_H = 1$ and $\theta_L = 0$, prices in first and second period, and equilibrium profit are:

$$P^*_{P^1,1} = \frac{2(1-q)(1-\delta)}{4-q-3\delta};$$
$$P^*_{P^1,2} = \frac{(\delta-q)(1-\delta)}{4-q-3\delta};$$
$$\pi^*_{P^1} = \frac{(1-q)(1-\delta)}{(4-q-3\delta)}$$

Hence substituting prices, we can get the marginal consumer, X_1 and X_2:

$$X_1 = \frac{P_{P^1 1} - P_{P^1 2}}{1-\delta} = \frac{2-\delta-q}{4-q-3\delta};$$
$$X_2 = \frac{P_{P^1 2}}{\delta-q} = \frac{1-\delta}{4-q-3\delta}$$

Consumer surplus, CS_{P^1} is derived as follows:

$$CS_{P^1} = \int_{X_1}^{1} (X - P_{P^1,1})dx + \int_{X_2}^{X_1} (\delta X - P_{P^1,2})dx + \int_{0}^{X_2} (qX)dx$$
$$= \left[\frac{X^2}{2} - XP_{P^1,1}\right]_{X_1}^{1} + \left[\frac{\delta X^2}{2} - XP_{P^1,2}\right]_{X_2}^{X_1} + \left[\frac{qX^2}{2}\right]_{0}^{X_2}$$

Substituting in the variables, we get:

$$\begin{aligned} CS^*_{P^1} &= \frac{4(1-\delta)(1+q-2\delta q)}{2(4-q-3\delta)^2} + \frac{\delta(1-q)^2 + 2q(1-\delta)(1-q)}{2(4-q-3\delta)^2} + \frac{q(1-\delta)^2}{2(4-q-3\delta)} \\ &= \frac{1+2q-3\delta q}{2(4-q-3\delta)} \end{aligned} \qquad (24)$$

Total welfare, $W^*_{P^1}$ is therefore:

$$W^*_{P^1} = CS^*_{P^1} + \pi^*_{P^1} = \frac{3-2\delta-\delta q}{2(4-q-3\delta)} \qquad (25)$$

Case when $q > \delta$

When $\theta_H = 1$ and $\theta_L = 0$, price and equilibrium profit are:

$$P^*_{P^1,q>\delta} = \frac{(1-q)}{2};$$
$$\pi^*_{P^1,q>\delta} = \frac{(1-q)}{4}$$

Substituting prices, we can get the marginal consumer, X_1:

$$X_1 = \frac{P_{P^1,q>\delta}}{1-q} = \frac{1}{2}$$

Consumer surplus, $CS_{P^1,q>\delta}$ is derived as follows:

$$CS_{P^1,q>\delta} = \int_{X_1}^{1} (X - P_{P^1,q>\delta})dx + \int_{0}^{X_1} (qX)dx = \left[\frac{X^2}{2} - XP_{P^1,q>\delta}\right]_{X_1}^{1} + \left[\frac{qX^2}{2}\right]_{0}^{X_1}$$

Substituting in the variables, we get:

$$CS^*_{P^1,q>\delta} = \frac{1+2q}{8} + \frac{q}{8} = \frac{1+3q}{8} \qquad (26)$$

Total welfare is hence:

$$W^*_{P^1,q>\delta} = CS^*_{P^1,q>\delta} + \pi^*_{P^1,q>\delta} = \frac{3+q}{8} \qquad (27)$$

Partial Protection (Piracy exists only in the second period)

When $\theta_H = 1$ and $\theta_L = 0$, prices in first and second period, and equilibrium profit are:

$$P^*_{P^2,1} = \frac{2(1-\delta q)(1-\delta)}{4-\delta q-3\delta};$$

$$P^*_{P^2,2} = \frac{(\delta-\delta q)(1-\delta)}{4-\delta q-3\delta};$$

$$\pi^*_{P^2} = \frac{(1-\delta q)(1-\delta)}{(4-\delta q-3\delta)}$$

Hence substituting prices, we can get the marginal consumer, X_1 and X_2:

$$X_1 = \frac{P_{P^2 1} - P_{P^2 2}}{1-\delta} = \frac{2-\delta-\delta q}{4-\delta q-3\delta}; \qquad X_2 = \frac{P_{P^2 2}}{\delta-\delta q} = \frac{1-\delta}{4-\delta q-3\delta}$$

Consumer surplus, CS_{P^2} is derived as follows:

$$CS_{P^2} = \int_{X_1}^{1} (X - P_{P^2,1})dx + \int_{X_2}^{X_1} (\delta X - P_{P^2,2})dx + \int_{0}^{X_2} (\delta qX)dx$$

$$= \left[\frac{X^2}{2} - XP_{P^2,1}\right]_{X_1}^{1} + \left[\frac{\delta X^2}{2} - XP_{P^2,2}\right]_{X_2}^{X_1} + \left[\frac{\delta qX^2}{2}\right]_{0}^{X_2}$$

Substituting in the variables, we get:

$$CS^*_{P^2} = \frac{4(1-\delta)(1+q-2\delta^2 q)}{2(4-\delta q-3\delta)^2} + \frac{\delta(1-\delta q)^2 + 2\delta q(1-\delta)(1-\delta q)}{2(4-\delta q-3\delta)^2} + \frac{\delta q(1-\delta)^2}{2(4-\delta q-3\delta)^2}$$
$$= \frac{1+2q-3\delta^2 q}{2(4-\delta q-3\delta)} \qquad (28)$$

Total welfare, $W^*_{P^2}$ is therefore:

$$W^*_{P^2} = CS^*_{P^2} + \pi^*_{P^2} = \frac{3-2\delta-\delta^2 q}{2(4-\delta q-3\delta)} \qquad (29)$$

Results

The following result confirms our intuition.

Proposition 3

Consumer surplus is the highest in the scenario where there is piracy from the first period, and lowest in the scenario of no piracy. Formally, $CS^*_{P^1} > CS^*_{P^2} > CS^*_{NP}$.

Proof: From (24), and (28), we can find $CS^*_{P^1} - CS^*_{P^2} = \dfrac{9q(1-\delta)^3}{2(4-q-3\delta)(4-\delta q-3\delta)}$. This expression is always positive, since $\delta \in (0,1)$ and $q \in (0,1)$. Hence, $CS^*_{P^1} > CS^*_{P^2}$ for all δ and q defined.

From (22), and (28), $CS^*_{P^2} - CS^*_{NP} = \dfrac{9\delta q(1-\delta)^2}{2(4-\delta q-3\delta)(4-3\delta)}$. Similarly, this expression is always positive and above zero. Hence, $CS^*_{P^2} > CS^*_{NP}$ and together with the above, gives us $CS^*_{P^1} > CS^*_{P^2} > CS^*_{NP}$ for all δ and q defined.

Proposition 4

Comparing among the three scenarios, total social welfare is maximum when piracy is allowed in the first period, and is minimum when piracy is not allowed at all.[35] *Formally,* $W^*_{P^1} > W^*_{P^2} > W^*_{NP}$.

Proof: Observe from (25) and (29), $W^*_{P^1} - W^*_{P^2} = \dfrac{3q(1-\delta)^3}{2(4-q-3\delta)(4-\delta q-3\delta)}$. This expression is always positive because $\delta \in (0,1)$ and $q \in (0,1)$ Thus, $W^*_{P^1} > W^*_{P^2}$ for all δ and q defined.

Observe from (23) and (29), $W^*_{P^2} - W^*_{NP} = \dfrac{3\delta q(1-\delta)^2}{2(4-q-3\delta)(4-3\delta)}$. As above, this expression is always positive. Therefore, $W^*_{P^2} > W^*_{NP}$, and together with above, gives us $W^*_{P^1} > W^*_{P^2} > W^*_{NP}$ for all δ and q defined.

Discussion

Prior to this welfare analysis, we looked at the producer's side where it was optimal for movie producers to deter piracy totally. Here, we investigated the effects on consumer surplus and total social welfare. From proposition 3, we find that consumer surplus is maximized with full piracy.

As is common in many situations we find that the profits and consumer surplus are of opposing nature, such that one increase leads to the decrease of the other. In our model, it can be seen that in the no piracy case, profit is the highest while consumer surplus is the lowest. In the case of full piracy, the opposite happens. When sum to total welfare, we get the same rankings as consumer surplus, as shown in proposition 4. This

[35] Although there are 2 cases under the scenario where piracy exist from the 1st period, it can be checked that for each case, the consumer surplus and total social welfare will be the highest under the condition defined.

means when piracy increases, the increase in consumer surplus outweighs the decrease in producer's profits.

However, if we were to allow piracy to be rampant, it will become very unfair to the movie producers and the people involved in the movie business. Companies may find it unsustainable to produce movies when profits are diminishing. Movies with special effects, elaborate sets and good actors and actresses will no longer be affordable, consumers will hence have less entertainment. Most importantly, there can never be pirated versions without the originals. Therefore, consumer and social welfare will decrease eventually in the long run if no piracy preventing measure is taken at all.

In view of the above arguments, one can propose that the case of allowing piracy only in the second period may be a desired strategy for the society as a whole. As explained previously, the producer can appropriate most of the profits from the first period where the film is just released. Thus, restricting piracy in first period will then ensure profitability and retain the incentives for producers to make new movies as well. Allowing piracy from the second period onwards will enable the low value consumers to see the movie and thus will enhance consumer surplus and overall welfare.

Conclusion

Here we presented a two period model to depict the impact of movie piracy on the movie theatres. In our model, there can be no piracy, or it can exist in the first period or second period. We refer to them as the first, second and third scenario respectively.

In our model, we found out that prices and profits of producers are decreasing with the availability of pirated version. First-period demand however, increases with piracy. From the producers' point of view, its optimal strategy is to eliminate piracy totally. However, this may not be realistic; thus 'delaying' piracy to the second period is the second best alternative available to the movie producers.

After analyzing the producer's side, we calculated the consumer surplus and total social welfare. We found both of them increase with piracy. This is understandable as piracy brings more choices and at lower prices. Thus, consumers and movie producers have opposing interests. A desired strategy thus would be one where producers and consumers can "meet halfway" and the proposed case of partial protection, which restricts piracy in the first-period only, but allows it from the second-period onwards, can be a possible solution. As also we know from reality that for the producers, first few weeks (i.e. first period in our model) of the movie release is of utmost importance as most of the revenue is generated within this period for a new release, hence a protection in that period is important to the producers.

This strategy also emphasizes on the role of government as a middleman to mitigate the clash of interests between consumers and producers. The authority should take this into account and seek to find an optimal time length of protection. They can achieve this by defining and adjusting instruments like copyright laws and costs of protection, such that they can deter piracy and increase social welfare while sustaining original producer's incentive to produce new movies.

Lastly, there are more areas to be researched to develop a theory on movie piracy since it is a relatively new topic. With our model, we have only considered the profits from selling tickets in theatres (direct appropriation). However, movie companies are known to increase their revenues by selling movies-related items, collectibles, endorsements and licenses to merchants using their trademark (indirect appropriation). Hence, one area of research could be investigating the profitability of indirect appropriation in the presence of piracy and whether piracy helps in increasing the sales of the 'by-products' of movies. Also, we concentrated only on movies shown in theaters. In reality, movie companies sell VCD or DVD versions after a few months of theater release. One important area of theoretical research can hence be looking at the impact of piracy on the VCD and DVD markets for movies.

References

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

Banerjee, S., and Lin, P. (2003), "Downstream R&D, Raising Rivals' Cost, and Input price Contracts, *International Journal of Industrial Organization*, Vol 21, 79-96.

Banerjee, D., Khalid, A. and Sturm J.E. (2005), "Socio-Economic Development and Software piracy - An Empirical Assessment, *Applied Economics*, Forthcoming.

Belleflamme, P., (2002), "Pricing Information Goods in the Presence of Copying", *mimeo*, QueenMary University of London.

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 R.P. Rumelt, (1991). "Software Piracy - An Analysis of Protection Strategies", *Management Science* 37,125-139.

Duchne, A. and P. Waelbroeck, (2001). "Welfare implications of illegal copies: the case of peer-to-peer distribution technologies", *mimeo*, CERAS-ENPC, Paris.

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.

Gayer, A and 0.Shy, (2003), "Copyright Protection and Hardware Taxation", *Information Economics and Policy* 15, 467-483.

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.

Gopal, R. D. and Sanders L. G., (2000), "Global Software Piracy: You Can't Get Blood out of a Turnip", *Communications of the ACM*, Vol.43, No. 9, 83-89.

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).

Hui, Kai Lung, and Png, I.P.L. (2003). "Piracy and the Legitimate Demand for Recorded Music", *Contributions to Economic Analysis & Policy*, Vol. 2 No. 1, Article 11.
Husted, B. W. (2000), "The Impact of National Culture on Software Piracy", *Journal of Business Ethics*, Vol. 26, No. 3, 197-211.
Katz, Michael L., and Shapiro, Carl (1985). "Network Externalities, Competition, and Compatibility", *American Economic Review*, Vol. 75, No. 3, 424-440.
King, Stephen P., and Lampe. Ryan (2003). "Network Externalities, Price Discrimination and Profitable Piracy", *Information Economics and Policy*. Vol. 15, Issue 3, 271-290.
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.
Ordover, J., Saloner, G., and Salop, S. C., (1990), "Equilibrium Vertical Foreclosure", *American Economic Review*, 80, 127-142.
Peitz, M. and P. Waelbroeck, (2003b). "An Economist's Guide to the Technology, Law and Business of Music Distribution", Working Paper, University of Mannheim and ECARES.
Salop, S. and Scheffman, D. (1983) "Raising Rivals' Costs", *American Economic Review*, Vol. 73, 267-271.
Salinger, M., (1988), "Vertical Mergers and Market Foreclosure", *Quarterly Journal of Economics*, 77, 345-356.
Shy, O. and Thisse, J. F. (1999) "A Strategic Approach to Software Protection". *Journal of Economics and Management Science*, Vol. 8, No.2, 163-190.
Sibley, D. S. and Weisman, D. L. (1998) "Raising Rivals' Costs: The Entry of an Upstream Monopolist into Downstream Markets". *Information Economics and Policy,* Vol. 10, 451-470.
Slive, J. and Bernhardt, D. (1998) "Pirated for Profit". *Canadian Journal of Economics*, Vol. 31, No. 4, 886-899.
Takeyama, L. N. (1994) "The Welfare Implications of Unauthorized Reproduction of Intellectual Property in the Presence of Demand Network Externalities". *Journal of Industrial Economics*, No. 2, 155-165.
Takeyama, L.N., (1997). "The Intel-temporal Consequences of Unauthorized Reproduction of Intellectual Property", *Journal of Law and Economic*s 40, 511 -522.
Takeyama, L.N., (2002). "Piracy, Asymmetric Information and Product Quality Revelation" *mimeo*, Amherst College.
Watt, R. (2000), Copyright and Economic Theory – Friends or Foes, Edward Elgar.

Internet References

BSA and IDC Global Software: May 2005 – http://www.bsa.org
Motion Picture Association of America, www.mpaa.org