ANALYZING PROTECTION STRATEGIES FOR ONLINE SOFTWARE DISTRIBUTION

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ABSTRACT

The enormous popularity of the Internet and the tremendous advances in communication technology have opened a new distribution channel for the software firms. However, at the same time, the Internet also makes the distribution of pirate software much easier. In order to analyze software firms' protection strategies for online software distribution, a game theory base model is presented in the paper. We find that as long as pirate software is in the market, the firm that protects its software products can set a higher price for its products. We also find that when the software protection environment is fast improving, software firms should not protect their software products, since piracy can help them to lock in customers now and make higher profits in the near future. However, if the protection environment does not improve enough or even gets worse, firms that do not protect their software will not be able to benefit from the customers locked-in by pirate software, and they will be better off protecting their software products.

Keywords: Software Piracy, Software Distribution, and Software Protection Strategy.

1. Introduction

In the past, computer software was stored on physical storage medias like floppy disks and CDs, and sold through traditional channels. The enormous popularity of the Internet in recent years has demonstrated the commercial potential of offering computer software through the digital networks. Due to the advances in network technology, now consumers are able to procure software products directly through the Internet.

However, the lightning growth of the Internet usage has also led to a rise in software piracy. Software counterfeiters are moving their business from the street markets to the World Wide Web. Lyman (2001) quotes a U.S. Customs official as saying, "The explosive growth of Internet users has spawned an equally explosive growth of Internet abusers. Cyber-savvy criminals increasingly use the speed and anonymity of the Internet to sell and distribute counterfeit software, music and videos worldwide. The potential revenue losses to legitimate businesses are enormous."

In order to combat online software piracy, many solutions have been proposed. These solutions generally fall into two categories -- preventive controls and deterrent controls. Preventive controls use technology to increase the costs of engaging in acts of piracy. Such controls are usually undertaken through hardware- or software-based copy protection schemes. Examples of preventive controls include software encryption and hardware locks. Deterrent controls, in contrast to preventive controls, do not directly increase the cost of pirating software. Deterrence is achieved if an individual avoids criminal behavior out of the perceived threat or fear of the inherent elements of sanctions. Deterrent controls include government-to-government negotiations, educational campaigns, and legal activity related to expanding domestic copyright laws and seeking to enforce those laws (Gopal and Sanders 1997, 2000).

Since online software piracy has caused significant losses worldwide, the campaign against piracy has never stopped. According to a recent press release by the U.S. Department of Justice (www.cybercrime.gov/warezoperations.htm), law enforcement in the U.S. and around the world recently initiated aggressive operations against software piracy on the Internet. The targets of these operations included both individuals and organizations, known as "WAREZ" group, that operate within the United States and in various nations around the world and specialize in the illegal distribution over the Internet of copyrighted software programs.

Software firms are also doing their parts in the campaign. Leading software producers have been using advanced scanning tools to search and monitor the Internet. Microsoft announced on April 2, 2001 that it launched its second "Global Internet Sweep". In the action, Microsoft targeted counterfeiters in more than 20 nations around the globe and removed thousands of illegal offerings as part of its increasing fight against software piracy. According to Lyman (2001), Microsoft said in a statement that "[The scanning tool] expedites the process of finding Web pirates and has enabled Microsoft to identify and address thousands of illegal sites in a single day and work with Internet service providers and auction sites to remove illegal products from the Internet."

2. Literature Review and Research Questions

Software piracy is defined as the unauthorized use, duplication, distribution or sale of commercially available software (Moores and Dhillon 2000). The growing importance of software piracy has spurred research on the behavioral, ethical and economical understandings of software piracy. Eining and Christensen (1991) find that negative attitudes toward computers, individual perceptions concerning the net benefits of piracy and personal norms are related to the amount of pirated software possessed by business students. Glass and Wood (1996) study software piracy from an equity theory perspective and they find that an individual would provide another person with an illegal software copy if the individual owes a debt to the person or perceives that the other person will provide a favor in return. Gopal and Sanders (1997) find that gender (females pirate less), age (older individuals pirate less), and ethical propensity (ethical individuals pirate less) are related to software piracy behavior. They also argue that the effect of antipiracy controls is positive only when the antipiracy measures appropriate a higher price from the software pirates. Gopal and Sanders (1998) point out that the government's incentive to enact and enforce copyright laws are closely related to the size of the domestic software industry. Gopal and Sanders (2000) have studied the income effect on software piracy. They argue that indexing the price of the software to the per-capital GNP level in the concerned country will be an effective way to combat piracy.

However, researchers have also shown that piracy is not always harmful to the firms. Conner and Rumelt (1991) argue that when positive network externality is present, software piracy can raise firm profits and lower selling prices. They argue that piracy protection raises the cost of pirating, causing some would-be pirates to buy and others to do without the product. The resultant smaller user base produces a lower software value and may actually reduce profits and induce the firm to increase the price. Givon, Mahajan and Muller (1995) further complement the arguments by using innovation diffusion models to study piracy. They argue that for certain types of software, where the word-of-mouth interaction among users and potential users is critical to the growth of the user base over time, pirates play an important role in converting potential users into users of the software, many of whom legally purchase the software. They demonstrated their modeling approach by analyzing the diffusion of spreadsheets and word processors in the United Kingdom. The results indicated that since the late 1980s, out of every seven software users, six had pirated copies. On the other hand, the pirates significantly influenced the potential users to adopt this software. In fact, they contributed to generating more than 80% of the unit sales for these two types of software. Gopal and Sanders (1997) suggest that deterrent controls can potentially increase profits, while preventive controls actually decrease profits.

One interesting phenomenon unique to online software distribution is that the distribution cost is almost zero. When software products are distributed over the Internet, no packaging, delivering or physical storefronts are needed. Moreover, "zero distribution cost" is not only true to the legitimate firms, but it is also true to the pirate firms. Traditionally, the distribution costs for pirate firms are higher, since they cannot use the widespread legitimate distribution channels, and they have to take loss if their products are seized before they hit the market. But when the pirates use the Internet to distribute pirate software, they can avoid those higher costs, and take advantage of the virtual world. Due to the above reasons, we assume the distribution costs for both legitimate and pirate firms are zero, and this assumption in part makes our analysis different from previous researches on software protection strategies.

Another difference between our research and previous ones is that we believe we are the first to look at the issue from the consumer switching costs perspective. In this paper, we base our analysis on the fact that software products are characterized by high consumer switching costs. Software users tend to buy the software they previously used for the following reasons,

(1) It takes quite some efforts to learn how to use software.
(2) The installation and implementation of a different software system is not a trivial task at all.
(3) Software firms often give deep discounts to continuous buyers[1].

[1] For example, Microsoft offers both "standard" version and "upgrade" version of operating systems. The installation of a "standard" version operating system does not require an existing old version of the same operating system, while the

The role of consumer switching costs has been previously investigated by Klemperer, Padilla, and many others. Klemperer (1987) points out that ex ante homogeneous products may, after the purchase of one of them, be ex post differentiated by switching costs including learning costs, transaction costs, or "artificial" costs imposed by firms, such as repeat-purchase discounts. He suggests that the noncooperative equilibrium in an oligopoly with switching costs may be the same as the collusive outcome in an otherwise identical market without switching costs. However, the prospect of future collusive profits leads to vigorous competition for market share in the early stages of a market's development. Beggs and Klemperer (1992) study the evolution of duopolists' prices and market shares in an infinite-period market with consumer switching costs. They show prices (and profits) are higher than without switching costs. Padilla (1992) finds that switching costs make overall competition less severe. Similar results are obtained by Padilla (1995) in a symmetric Markovian perfect equilibrium of an infinite-horizon stochastic model.

High consumers switching costs may have profound impacts on software firms' protection strategies. It is argued that because of consumer switching costs, piracy can help to lock-in consumers in the first period, and lead to higher profits in the future. This argument seems right, but as we are going to show, it is not always true. We believe that under some circumstances, software firms are better off not protecting their products, but in other cases, protecting is a better choice.

The rest of the paper is organized as follows. Section 3 presents the model. Section 4 presents the analysis. Conclusions and future research directions are discussed in Section 5.

3. The Model

Let us consider a software market that has two periods with complete and perfect information. Two software firms, *A* and *B*, are present in the market in both periods. Each firm produces a software product in period one, and an upgrade version of the software in period two. The marginal costs for producing the software products are assumed to be zero, and the fixed costs are assumed to be the same for both firms in each period. Let us denote the fixed costs in the two periods by C_{F1} and C_{F2} respectively. We denote firm *A* and *B*'s prices in period i ($i=1,2$) by p_{Ai} and p_{Bi}, demand they face by q_{Ai} and q_{Bi}, and profits they realize by π_{Ai} and π_{Bi} respectively.

A pirate firm, *AP*, pirates firm *A*'s product. In period i ($i=1,2$), *AP*'s fixed cost is C_{FPi} and marginal cost is zero. We also denote firm *AP*'s price, demand and profit in period i ($i=1,2$) by p_{APi}, q_{APi} and π_{APi} respectively. Following Klemperer (1987), we assume each firm will try to maximize its profits in each period. Firms discount the profits in the second period by δ, and we use π_A and π_B to denote the total profits *A* and *B* realize over the two periods.

In each period every consumer has demand for only one software product. These consumers' preferences for different software products can be represented as uniformly distributed along a line segment [0, 1], with the products of firm *A* and *B* at 0 and 1 respectively. We assume the pirate software has the same quality as the original one, and thus the product of *AP* is also located at 0. A consumer at z ($z \in [0,1]$) incurs a "using" cost of zt for using *A* or *AP*'s software, and $(1-z)t$ for using B's software, where t is the unit cost of use. The "using" costs may include the learning costs, installation costs and the maintenance costs etc. Thus, a consumer at z incurs the cost $p_{Ai} + zt$ if he buys *A*'s software, and $p_{Bi} + (1-z)t$ if he buys *B*'s.

In period i ($i=1,2$), the probability of being caught using pirate software is P_i. If a consumer is caught using pirate software, he may be required to pay a big fine, or even sentenced to jail. He will also incur the costs of replacing the pirate software, and the loss of good will. For simplicity, we use F_i to denote the using costs in this case. Thus, if a consumer chooses to buy pirate software in period i ($i=1,2$), his expected cost is $(p_{APi} + zt)(1-P_i) + P_i(p_{APi} + F_i)$.

There are N_1 consumers in the market in period one, and N_2 new consumers will join the market in period two. We assume that the consumers are risk averse. In each period every consumer has demand for one unit of software product, and we assume the consumers' reservation prices are high enough that all consumers buy. Following Beggs and Klemperer (1992), we also assume it is too costly for a consumer to switch to buying from a firm other than the one from which he has previously bought.

4. The Analysis

4. 1. Period One

In the first period, consumers' cost of buying pirate software can be written as $z(1-P_1)t + P_1F_1 + p_{AP1}$. Figure 1 illustrates the purchase decisions consumers face in this period. Since $P_1 \le 1$, we have $(1-P_1)t \le t$, which means the slope of the line representing the costs of buying pirate software is smaller than that of the line

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"upgrade" version requires one. The price of the "upgrade" version is much cheaper than that of the "standard" version.

representing the cost of buying *A*'s software. So, as the value of $P_1F_1 + p_{AP1}$ varies, the line representing the cost of buying pirate software can be one of the lines ranging from l_1 to l_6, as shown in Figure 1.

Based on his preference, a consumer will choose the software product that is the least expensive to him. When there is no piracy, consumers located at z_0 will be indifferent between buying from *A* and *B*. i.e., consumers located in [0, z_0] will buy from A, and consumers located in [z_0, 1] will buy from B.

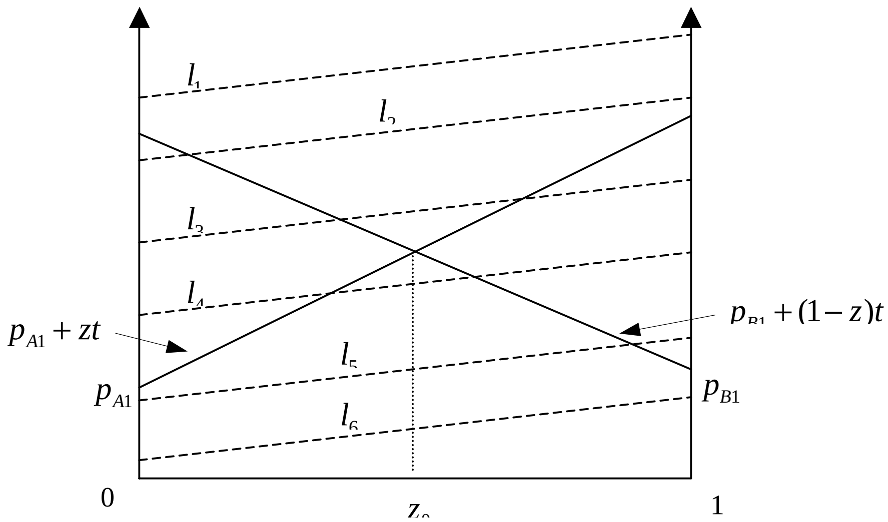

Figure 1. Consumer purchase decisions in period one given p_{A1} and p_{B1}.

When the line representing the cost of buying pirate software is l_1, l_2 or l_3, piracy will not have any impacts on the market, since the market is entirely covered by legitimate software. On the other hand, when the line representing cost of buying pirate software is l_6, pirate software will take the entire market and no consumer will buy legitimate software. Things are a little more complicated when l_5 is the line representing the cost of buying pirate software. In this case, the pirate software (*AP*'s software) drives the original legitimate software (*A*'s software) totally out of the market, and also takes some market share from *B*. However, we believe the above situations are not likely to be true in the real world, since we all observe the coexistence of legitimate and pirate software. As Conner and Rumelt (1991) says, "Any model of software piracy must account for the large observed volume of legitimate sale that persist despite the ease of copying unprotected programs and many protected ones". Hence we will concentrate our analysis on the situation where the line representing the cost of buying pirate software is like l_4. Figure 2 shows the market segmentation under this situation.

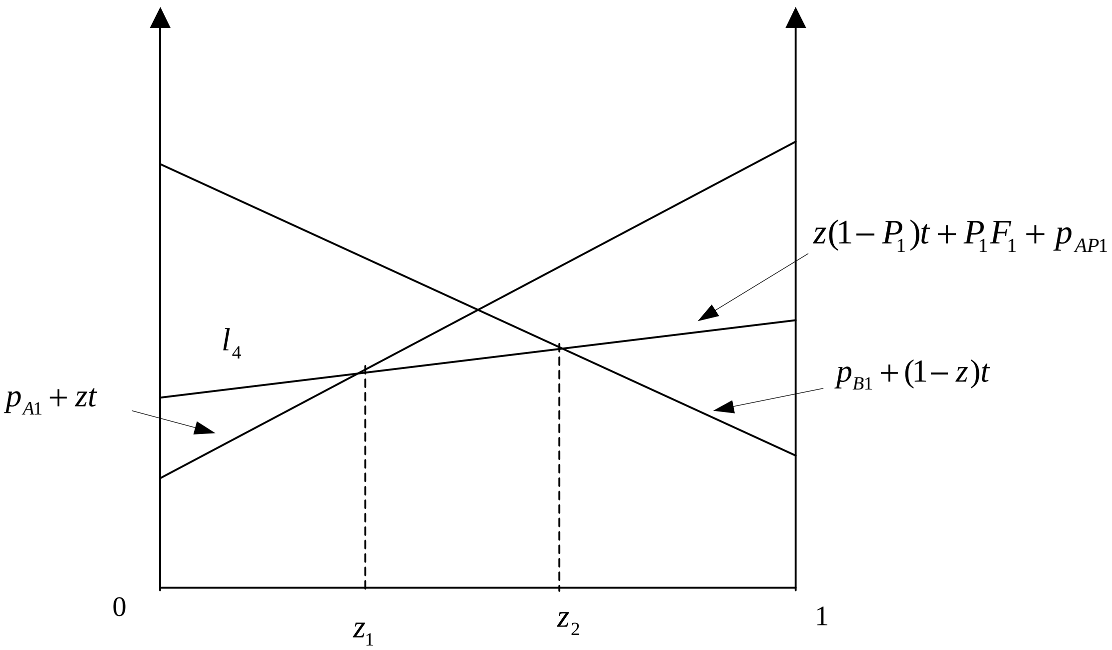

Figure 2. Market segmentation in period one.

Lemma 1. When $p_{A1} - P_1F_1 < p_{AP1} < \frac{(p_{B1}+t)P_1 + p_{A1}(2-P_1) - 2P_1F_1}{2}$, legitimate and pirate software coexists.

Proof: When p_{A1} and p_{B1} are given, depending on different values of p_{AP1}, l_4 will cross with other cost lines at different locations. When $p_{AP1} = p_{A1} - P_1F_1$, l_4 passes point (0, p_{A1}), and this is the lowest p_{AP1} value at which l_4 crosses with both other cost lines. When $p_{AP1} = \frac{(p_{B1}+t)P_1 + p_{A1}(2-P_1) - 2P_1F_1}{2}$, l_4 passes point ($\frac{p_{B1} - p_{A1} + t}{2t}$, $\frac{p_{A1} + p_{B1} + t}{2}$). This point is the cross point of the line representing the cost of buying from *A* and the line representing the cost of buying from *B*. Hence, $p_{AP1} = \frac{(p_{B1}+t)P_1 + p_{A1}(2-P_1) - 2P_1F_1}{2}$ is the highest p_{AP1} value that allows the coexistence of legitimate and pirate software.

Q.E.D.

From Figure 2 we can see that consumers at locations [0, z_1] will buy legitimate software from firm *A*, because at these locations,

$$p_{A1} + zt < z(1-P_1)t + P_1F_1 + p_{AP1} < p_{B1} + (1-z)t\ .$$

Consumers locates at [z_1, z_2] will buy pirate software from firm *AP*, because at these locations,

$$z(1-P_1)t + P_1F_1 + p_{AP1} < p_{A1} + zt$$

and

$$z(1-P_1)t + P_1F_1 + p_{AP1} < p_{B1} + (1-z)t\ .$$

Finally, consumers located in (z_2, 1] will buy legitimate software from firm *B*, because at these locations,

$$p_{B1} + (1-z)t < z(1-P_1)t + P_1F_1 + p_{AP1} < p_{A1} + zt\ .$$

Consumers at z_1 are indifferent between buying legitimate software from *A* and buying pirate software from *AP*, which means

$$p_{A1} + z_1t = z_1(1-P_1)t + P_1F_1 + p_{AP1}\ .$$

So,

$$z_1 = \frac{p_{AP} - p_{A1} + P_1F_1}{P_1t}$$

Consumers at z_2 are indifferent between buying pirate software from *AP* and buying legitimate software from *B*. For the same reason as the above, we have

$$z_2 = \frac{p_{B1} - p_{AP} + t - P_1F_1}{(2-P_1)t}$$

Hence, the demand each firm faces in period one is as follows,

$$q_{A1} = z_1 N_1 = \frac{p_{AP1} - p_{A1} + P_1 F_1}{P_1 t} N_1$$

$$q_{B1} = (1 - z_2) N_1 = [1 - \frac{p_{B1} - p_{AP2} + t - P_1 F_1}{(2 - P_1)t}] N_1$$

and

$$q_{AP1} = (z_2 - z_1) N_1 = [\frac{p_{B1} - p_{AP1} + t - P_1 F_1}{(2 - P_1)t} - \frac{p_{AP1} - p_{A1} + P_1 F_1}{P_1 t}] N_1$$

From the above, we can also get the profit each firm realizes in period one,

$$\pi_{A1} = p_{A1} q_{A1} - C_{F1} = \frac{p_{AP1} - p_{A1} + P_1 F_1}{P_1 t} p_{A1} N_1 - C_{F1}$$

$$\pi_{B1} = p_{B1} q_{B1} - C_{F1} = [1 - \frac{p_{B1} - p_{AP1} + t - P_1 F_1}{(2 - P_1)t}] p_{B1} N_2 - C_{F1}$$

and

$$\pi_{AP1} = p_{AP1} q_{AP1} - C_{FP1} = [\frac{p_{B1} - p_{AP1} + t - P_1 F_1}{(2 - P_1)t} - \frac{p_{AP1} - p_{A1} + P_1 F_1}{P_1 t}] p_{AP1} N_1 - C_{FP1}$$

Each firm will try to maximize its own profit. Let us denote the optimal prices by p^*_{A1}, p^*_{B1} and p^*_{AP1} respectively, and the optimal profits by π^*_{A1}, π^*_{B1} and π^*_{AP1}. Then p^*_{A1}, p^*_{B1} and p^*_{AP1} must satisfy the following first order conditions,

$$\frac{\partial \pi_{A1}}{\partial p_{A1}} \Big|_{p_{A1} = p^*_{A1}} = 0$$

$$\frac{\partial \pi_{B1}}{\partial p_{B1}} \Big|_{p_{B1} = p^*_{B1}} = 0$$

and

$$\frac{\partial \pi_{AP1}}{\partial p_{AP1}} \Big|_{p_{AP1} = p^*_{AP1}} = 0$$

Hence,

$$p^*_{A1} = \frac{P_1 (3 - P_1) t + 4 P_1 F_1}{12}$$

$$p^*_{B1} = \frac{(6 - 3P_1 - P_1^2) t + 4 P_1 F_1}{12}$$

$$p^*_{AP1} = \frac{P_1(3-P_1)t - 2P_1F_1}{6}$$

Proposition 1. $p^*_{A1} < p^*_{B1}$.

Proof: Working with p^*_{A1} and p^*_{B1}, we get

$$p^*_{A1} - p^*_{B1} = \frac{P-1}{4}$$

Since $P < 1$, $p^*_{A1} - p^*_{B1} < 0$.

Q.E.D.

Proposition 1 actually shows that firm *B* has a higher pricing power in period one.

Proposition 2. $q^*_{A1} + q^*_{AP1} > q^*_{B1}$.

Proof: From p^*_{A1}, p^*_{B1} and p^*_{AP}, we can get

$$q^*_{A1} + q^*_{AP1} - q^*_{B1} = \frac{N_1[(6-3P_1+P_1^2)t - 4P_1F_1]}{6(2-P_1)t}$$

From Lemma 1, we know that $p_{A1} - P_1F_1 < p_{AP1} < \frac{(p_{B1}+t)P_1 + p_{A1}(2-P_1) - 2P_1F_1}{2}$.

Substituting the prices gives

$$F_1 < \frac{(3-P_1)t}{2}$$

Since F_1 is definitely greater than zero, we have $0 < F_1 < \frac{(3-P_1)t}{2}$. Thus,

$$q^*_{A1} + q^*_{AP} - q^*_{B1} > \frac{N_1[(6-3P_1+P_1^2)t - 2P_1(3-P_1)t]}{6(2-P_1)t} = \frac{N_1(1-P_1)}{2}$$

Since $P < 1$, we have $q^*_{A1} + q^*_{AP1} - q^*_{B1} > 0$, and thus $q^*_{A1} + q^*_{AP1} > q^*_{B1}$.

Q.E.D.

Proposition 2 shows that although firm *B* has higher pricing power in period one, the combined market share of firm *A*'s product (legitimate and pirate) is larger. Since consumers tend to buy the upgrade of the software they previously used, this higher market share might give firm *A* an advantage in period two.

Based on p^*_{A1}, p^*_{B1} and p^*_{AP1}, we can also get the optimal profits of the firms as follows,

$$\pi^*_{A1} = \frac{[P_1(3-P_1)t + 4P_1F_1]^2 N_1}{144P_1t} - C_{F1}$$

$$\pi^*_{B1} = \frac{[(6-3P_1-P_1^2)t+4P_1F_1]^2 N_1}{144(2-P_1)t} - C_{F1}$$

and

$$\pi^*_{AP1} = \frac{[P_1(3-P_1)t-2P_1F_1]^2}{18P_1(2-P_1)t} N_1 - C_{FP1}$$

Proposition 3. $\pi^*_{A1} < \pi^*_{B1}$.

Proof: Working with π^*_{A1} and π^*_{B1}, we get

$$\pi^*_{A1} - \pi^*_{B1} = \frac{N_1(1-P_1)[16F_1^2P_1 - 8F_1P_1^2t + (P_1^3 + 9P_1 - 18)t^2]}{72(2-P_1)t}$$

Rewriting $\pi^*_{A1} - \pi^*_{B1}$ gives

$$\pi^*_{A1} - \pi^*_{B1} = \frac{N_1(1-P_1)[16P_1(F_1 - \frac{P_1t}{4})^2 + 9(P_1-2)t^2]}{72(2-P_1)t}$$

Since $0 < F_1 < \frac{(3-P_1)t}{2}$, $\pi^*_{A1} - \pi^*_{B1}$ achieves maximum value of $\frac{N_1(P_1-1)^3 t}{8}$ when $F_1 = \frac{(3-P_1)t}{2}$. Since $P_1 < 1$, $\frac{N_1(P_1-1)^3 t}{8}$ <0. Hence $\pi^*_{A1} < \pi^*_{B1}$.

Q.E.D.

From the above analysis we can see that firm *B* has a higher pricing power and profit in period one, but firm *A*'s product has a bigger market share thanks to the pirates.

4. 2. Period Two

In period two, N_2 new consumers will join the market. Based on their preferences, the N_2 new consumers will choose to buy legitimate software or to pirate. However, because of switching costs, the N_1 old consumers will stick to the firm that they previously bought from. I.e., legitimate users of firm *A* will still buy from firm *A*, and legitimate users of firm *B* will still buy from firm *B*. Users of pirate software in period one will choose whether to continue to use pirate software, or to buy legitimate software from firm *A*.

Since firms *A* makes fewer profits than firm *B* in the first period, it is apparent that if the software protection environment deteriorates in the second period, firm *A* will again makes a lower profit than firm *B*. In this case, the total profit (period one plus period two) firm *A* enjoys will be definitely lower than that of firm *B*. Hence, even though not protecting the software can help firm *A* to get a higher market share (legitimate and pirate combined), it is not a good strategy for firm *A* in terms of profits.

Since the result is quite easy to find when the protection environment deteriorates in the second period, we will not discuss this scenario in detail in the following analysis. In stead, we will focus on the scenarios where the protection environment improves in the second period. I.e., we assume that $P_2 > P_1$ and $F_2 > F_1$. Higher P and F values mean a better protection environment, but they do not guarantee that there is no piracy in the market anymore. As Lemma 1 shows, when

$p_{Ai} - P_i F_i < p_{APi} < \dfrac{(p_{Bi} + t)P_i + p_{Ai}(2 - P_i) - 2P_i F_i}{2}$ $(i = 1,2)$ legitimate and pirate software coexists.

Only when $p_{APi} > \dfrac{(p_{Bi} + t)P_i + p_{Ai}(2 - P_i) - 2P_i F_i}{2}$ $(i = 1,2)$ will pirate software be driven out of the market. In the following, we will analyze the two scenarios respectively.

4. 2. 1. Scenario 1: Pirate Software Remains in the Market

In this scenario, pirate software remains in the market in the second period. Figure 3 shows the market segmentation in this scenario. For the N_1 old consumers, because of switching costs, they will buy from the firm they previously bought from in period one. Since consumers located in $[0, z_1]$ bought from firm *A* in period one, they will buy from firm *A* again in period two. For the same reason, consumers located in $[z_2, 1]$ will buy from firm *B* again. Consumers located in (z_1, z_2) will choose between buying from firm A and buying pirate. According to Figure 3, consumers in (z_1, z_3) will buy legitimate software from firm A in the second period, since in period two at these locations, $p_{A2} + zt < z(1 - P_2)t + P_2 F_2 + p_{AP2} < p_{B2} + (1 - z)t$. At the same time, consumers located in (z_3, z_2) will continue to buy pirate, since at these locations, $z(1 - P_2)t + P_2 F_2 + p_{AP2} < p_{A2} + zt$.

Hence, we can get the demand each firm faces in the second period as follows,

$q_{A2} = z_1 N_1 + (z_3 - z_1)N_1 + z_3 N_2 = z_3(N_1 + N_2)$

$q_{B2} = (1 - z_2)N_1 + (1 - z_4)N_2$

and

$q_{B2} = (z_2 - z_3)N_1 + (z_4 - z_3)N_2$

From Figure 3, we can get

$$z_3 = \frac{p_{AP2} - p_{A2} + P_2 F_2}{P_2 t}$$

and

$$z_4 = \frac{p_{B2} - p_{AP2} + t - P_2 F_2}{(2 - P_2)t}$$

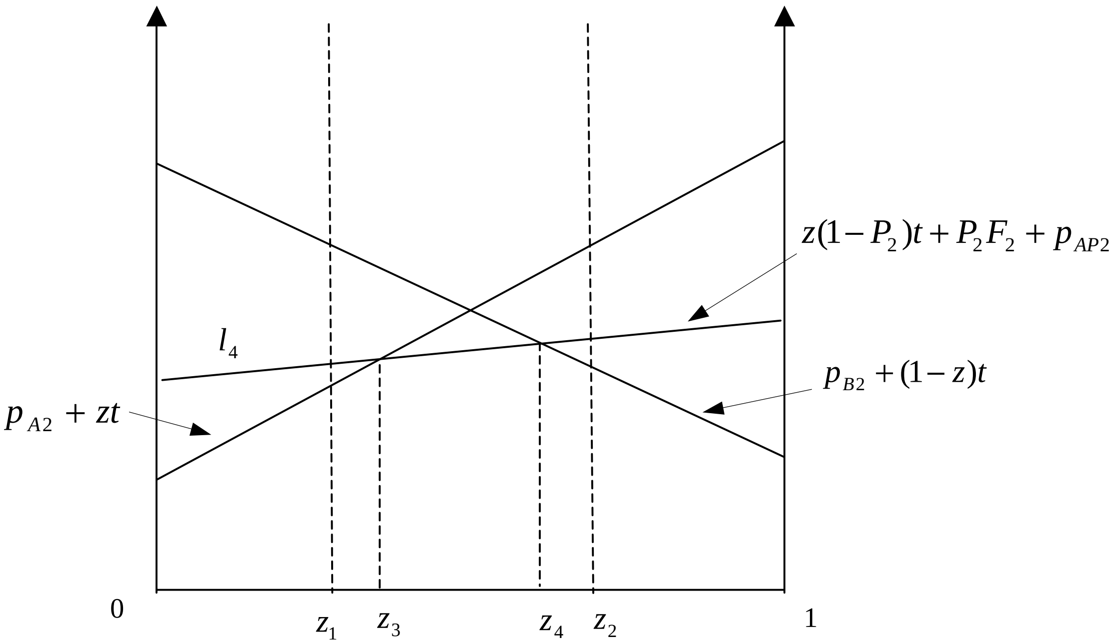

Figure 3. Market segmentation in period two when pirate software remains in the market.

Hence, we can also get the profit each firm gets in the second period as follows,

$$\pi_{A2} = p_{A2}q_{A2} - C_{F2} = \ p_{A2}\frac{p_{AP2} - P_{A2} + P_2F_2}{P_2t}(N_1 + N_2) - C_{F2}$$

$$\pi_{B2} = p_{B2}q_{B2} - C_{F2} = p_{B2}[(1 - z_2)N_1 + (1 - \frac{p_{B2} - p_{A2} + t - P_2F_2}{(2 - P_2)t})N_2] - C_{F2}$$

and

$$\pi_{AP2} = p_{AP2}q_{AP2} - C_{FP2}$$

$$= p_{AP2}[(z_2 - \frac{p_{AP2} - p_{A2} + P_2F_2}{P_2t})N_1 + (\frac{p_{B2} - p_{AP2} + t - P_2F_2}{(2 - P_2)t})N_2] - C_{FP2}$$

If we let α be $\frac{(2 - P_2)t[N_2(1 - \frac{t - F_2P_2}{(2 - P_2)t}) + N_1(1 - z_2)]}{2N_2}$, and let β be $-\frac{P_2(2F_2N_1 + 2F_2N_2 - F_2N_1P_2 - 2N_1t - 3N_2t + N_1P_2t + N_2P_2t - 2N_1tz_2 + N_1P_2tz_2)}{6(2N_1 + 2N_2 - N_1P_2)}$, then from the first order conditions, we can get

$$p^*_{A2} = \frac{F_2P_2}{2} + \beta$$

$$p^*_{B2} = \alpha + \beta$$

and

$$p^*_{AP2} = 2\beta$$

Also, we can get the optimal profit each firm gets as the following,

$$\pi^*_{A2} = \frac{(N1 + N2)(\frac{F_2P_2}{2} + \beta)^2}{P_2t}$$

$$\pi^*_{B2} = (\alpha + \beta)\{N_1(1 - z_2) + N_2[1 - \frac{1}{(2 - P2)t}(t - F_2P_2 + \alpha - \beta)]\}$$

and

$$\pi^*_{AP2} = 2\beta[N_1z_2 - \frac{(N_1 + N_2)(\frac{F_2P_2}{2} + \beta)}{P_2t} + \frac{N_2}{(2 - P_2)t}(t - F_2P_2 + \alpha - \beta)]$$

Proposition 4. $p_{A2}^* < p_{B2}^*$.

Proof: $p_{A2}^* - p_{B2}^* = \frac{F_2 P_2}{2} - \alpha = -\frac{(1-P_2)t}{2} - \frac{tN_1(2-P_2)(1-z_2)}{2N_2}$. Since $0 < P_2 < 1$ and $0 < z_2 < 1$, we have $\frac{(1-P_2)t}{2} > 0$ and $\frac{tN_1(2-P_2)(1-z_2)}{2N_2} > 0$. Hence, $p_{A2}^* - p_{B2}^* < 0$, which means $p_{A2}^* < p_{B2}^*$.

Q.E.D.

Proposition 4 shows that when there is piracy in the second period, no matter how much P_2 and F_2 have improved, firm *A*'s price will be still lower than firm *B*'s. Hence, as long as piracy is in the market, firm *A*'s price will be lower than firms *B*'s.

In this scenario, it is hard to say which firm makes more profit in the second period. For example, if we assume $t = 100$, $z_2 = 0.8$, $N_1 = 1000$, $N_2 = 1000$, $F_2 = 100$, and $P_2 = 0.4$, we will find $\pi_{A2}^* = 27569$ and $\pi_{B2}^* = 30173$, and thus $\pi_{A2}^* < \pi_{B2}^*$. However, if we keep all the other values unchanged, and set P_2 to 0.9, we will find $\pi_{A2}^* = 54983.6$ and $\pi_{B2}^* = 39290.9$, which means $\pi_{A2}^* > \pi_{B2}^*$.

When $\pi_{A2}^* < \pi_{B2}^*$, it is obvious that not protecting the software products is not a good strategy, since firm *A* makes lower profits in both periods. When $\pi_{A2}^* > \pi_{B2}^*$, the problem is a little more complicated. Since both firms discount profits in the second period by δ, we can write the total profit each firm gets as the following,

$$\pi_A^* = \pi_{A1}^* + \delta\pi_{A2}^*$$

and

$$\pi_B^* = \pi_{B1}^* + \delta\pi_{B2}^*$$

Since firms discount profits in the second period, the profit gain in the second period becomes less significant if the discount factor δ is too small. It is obvious that the longer the waiting period is, the smaller δ will be. Hence, even when firm *A* makes a higher profit in period two, if the waiting is too long, the total profit firm *A* enjoys will still be lower than firm *B*'s.

4. 2. 2. Scenario 2: Pirate Software is no longer in the market

When $p_{AP} > \frac{(p_B + t)P + p_A(2-P) - 2PF}{2}$, pirate software will be driven out of the market. Figure 4 shows the market segmentation in this scenario.

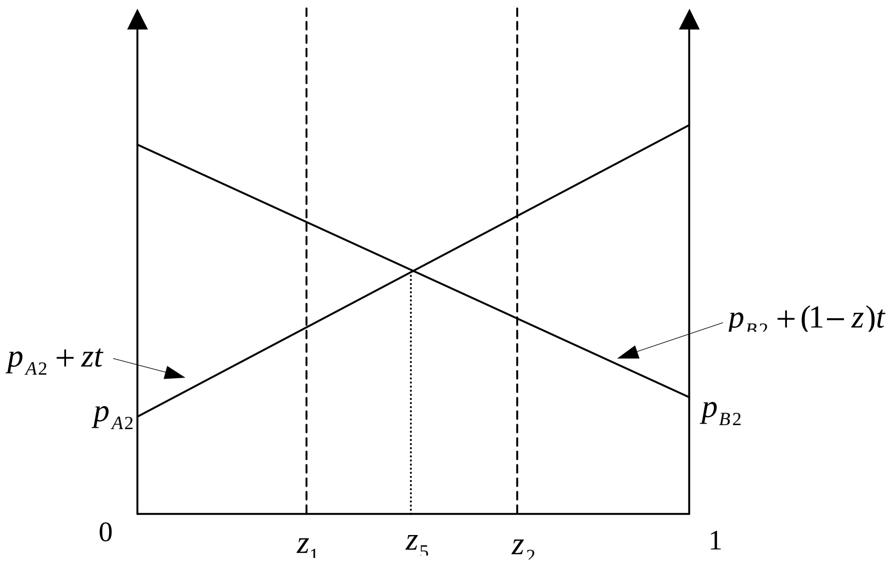

Figure 4. Market segmentation when pirate software is driven out of the market.

For the same reason as in period one, new consumers located at z_5 are indifferent between buying from *A* and *B*. Thus, we have

$$p_{A2} + z_5 t = p_{B2} + (1 - z_5)t$$

i.e.,

$$z_5 = \frac{p_{B2} - p_{A2} + t}{2t}$$

New consumers located in [0, z_5] will buy from firm *A*, while new consumers located in (z_5, 1] will buy from firm *B*. For the N_1 old consumers, because of the high switching costs, they buy from the software firm they previously bought from. Since there is no more pirate software available in this period, consumers who previously bought pirate software will buy from the legitimate software firm *A*. Hence, the demand each firm faces in period two is as follows,

$$q_{A2} = z_5 N_2 + q_{A1} + q_{AP1} = \frac{p_{B2} - p_{A2} + t}{2t} N_2 + q_{A1} + q_{AP1}$$

and

$$q_{B2} = (1 - z_5)N_2 + q_{B1} = (1 - \frac{p_{B2} - p_{A2} + t}{2t})N_2 + q_{B1}$$

From the above, we can also get the profit each firm gets in period two,

$$\pi_{A2} = p_{A2} q_{A2} - C_{F2} = p_{A2}(\frac{p_{B2} - p_{A2} + t}{2t} N_2 + q_{A1} + q_{AP}) - C_{F2}$$

and

$$\pi_{B2} = p_{B2} q_{B2} - C_{F2} = p_{B2}[(1 - \frac{p_{B2} - p_{A2} + t}{2t})N_2 + q_{B1}] - C_{F2}$$

Proposition 5: $p^*_{A2} > p^*_{B2}$

Proof: From the first order conditions, we get

$$p^*_{A2} = \frac{(3N_2 + 2N_1 + 2q_{A1} + 2q_{AP})t}{3N_2}$$

and

$$p^*_{B2} = \frac{(3N_2 + 2N_1 + 2q_{B1})t}{3N_2}$$

Hence, $p^*_{A2} - p^*_{B2} = \frac{2(q_{A1} + q_{AP} - q_{B1})t}{3N_2}$. Since Proposition 2 shows $q_{A1} + q_{AP} > q_{B1}$, we have $p^*_{A2} > p^*_{B2}$.

Q.E.D.

Proposition 6. $\pi^*_{A2} > \pi^*_{B2}$.

Proof: From p^*_{A2} and p^*_{B2} we can also get the profits as follows,

$$\pi^*_{A2} = \frac{(3N_2 + 2N_1 + 2q_{A1} + 2q_{AP})^2 t}{18N_2}$$

$$\pi_{B2}^{*} = \frac{(3N_2 + 2N_1 + 2q_{B1})^2 t}{18N_2}$$

$\dfrac{\pi_{A2}^{*}}{\pi_{B2}^{*}} = (\dfrac{3N_2 + 2N_1 + 2q_{A1} + 2q_{AP}}{3N_2 + 2N_1 + 2q_{B1}})^2$. Since $q_{A1} + q_{AP} > q_{B1}$, $\dfrac{\pi_{A2}^{*}}{\pi_{B2}^{*}} > 1$. So $\pi_{A2}^{*} > \pi_{B2}^{*}$.

Q.E.D.

Proposition 5 and 6 show that when there is no pirate software in the second period, the larger consumer base firm *A* gets in the first period gives firm *A* higher pricing power in period two, and enables it to get a higher profit as well. So, in this case, although piracy hurts firm *A* more in the first period one, it is actually beneficial to firm *A* in period two.

Proposition 7. When

$\delta \geq \dfrac{9N_1N_2(2-P)(1-P)[(18-9P-P^3)t^2 - 16F^2P + 8FP^2t]}{\{4N_1FP + [18N_2(2-P) + N_1(P^2 + 15P - 30)]t\}^2}$, we have $\pi_A \geq \pi_B$;

When

$\delta < \dfrac{9N_1N_2(2-P)(1-P)[(18-9P-P^3)t^2 - 16F^2P + 8FP^2t]}{\{4N_1FP + [18N_2(2-P) + N_1(P^2 + 15P - 30)]t\}^2}$, we have $\pi_A < \pi_B$.

Proof: Since firms discount profits in the second period by δ, we have

$\pi_A = \pi_{A1} + \delta\pi_{A2}$ and $\pi_B = \pi_{B1} + \delta\pi_{B2}$

Thus, when $\pi_A - \pi_B = 0$, we have $\delta = \dfrac{\pi_{B1} - \pi_{A1}}{\pi_{A2} - \pi_{B2}}$, which means

$$\delta = \frac{9N_1N_2(2-P)(1-P)[(18-9P-P^3)t^2 - 16F^2P + 8FP^2t]}{\{4N_1FP + [18N_2(2-P) + N_1(P^2 + 15P - 30)]t\}^2}$$

So, When $\delta \geq \dfrac{9N_1N_2(2-P)(1-P)[(18-9P-P^3)t^2 - 16F^2P + 8FP^2t]}{\{4N_1FP + [18N_2(2-P) + N_1(P^2 + 15P - 30)]t\}^2}$, we have $\pi_A \geq \pi_B$,

and then $\delta < \dfrac{9N_1N_2(2-P)(1-P)[(18-9P-P^3)t^2 - 16F^2P + 8FP^2t]}{\{4N_1FP + [18N_2(2-P) + N_1(P^2 + 15P - 30)]t\}^2}$, we have $\pi_A < \pi_B$.

Q.E.D.

Interestingly enough, in this case, the above finding suggests that software firms should not protect their online software distribution if the software protection environment is fast improving, since piracy can help them to gain market share now, and enable them to get higher profits in the near future. However, if the software protection environment does not improve enough, or is even worsening, the firms will have to protect their products and fight piracy, since piracy hurts profits now, and long wait makes the future profit gain less desirable.

5. Conclusions and Directions for Future Research

This article has attempted to analyze software firms' protection strategies for online software distribution. We find that as long as pirate software is in the market, the firm that protects its products will have a higher pricing power than the firm that does not protect. We also find that if the software protection environment is quickly improving, firms should not protect their software, since piracy can help them to lock in customers now and make higher profits in the near future. However, if the protection environment does not improve enough or even gets worse, firms that do not protect their software will not be able to benefit from the customers locked-in by pirate software, and they will be better off protecting their software products.

In order to determine how long piracy can stay in the market, we have to look at the two main measurements of software protection in a nation. The first measurement is if the nation has good laws covering software piracy, and the second measurement is if the government can effectively enforce the laws. In our model, the first measurement is captured by F, and P represents the second measurement. Hence, increasing F or P can improve software protection environment, and signify that piracy will be driven out of the market soon. However, the software protection environment nowadays is still far from satisfactory. According to the Sixth Annual Business Software Alliance (BSA) Global Software Piracy Study, the worldwide revenue losses due to piracy were calculated at $11.75 billion in 2000. Moreover, the worldwide software piracy rate in 2000 did not decline, but instead increased slightly to 37%. Since there is no indication that piracy will be driven out of the market soon, software firms will be better off protecting their software products.

In the campaign against piracy, global collaboration is of greater importance in the Internet era. The Internet has no boundaries, which makes it the ideal tool for distributing software products globally. However, nations have boundaries and software protection environments vary tremendously across nations. Different legal and economic systems lead to different evolution paths for software protection environments in different countries. Thus, international coordination is required to make sure there is no safe heaven for the pirates in the whole world.

One limitation of our research is that upgrade prices are not included in the model. The reason is that if we add two upgrade prices in the second period, there will be five prices to consider, and the model will become intractable. In fact, offering continuous buyers a lower upgrade price might be an effective strategy against piracy, because when users realize that if they buy legitimate copies now, they will pay a lot less when they upgrade, they will tend to favor legitimate copies more. Hence, building a model that includes upgrade prices will definitely be one of our future research directions.

Another limitation of our research is that our analysis is based on a model that only includes two firms and two periods, and we assume in the model that every consumer only buys one copy. We also assume that the distribution of consumer preference is linear, and consumers make purchasing decisions independently. Although these assumptions are based previous literatures (Varian 1980, Klemperer 1987 and Moorthy 1988), it will definitely help to improve the applicability and usability of our results if we can consider more firms in the model, extend to model to include unlimited periods, or assume a more general form for the consumer preference distribution.

The emergence of Open Source Software such as Linux presents a new problem to the study of software piracy. It is quite common to think that there is no point to pirate Open Source Software since they are free. However, in fact, not all Open Source Software is free. For example, although no company owns the intellectual property of Linux, all Linux vendors sell the software for a price. For example, you can get Red Hat Linux 7.3 for $59.95 from www.redhat.com, while you have to pay $2,499.00 for Red Hat Linux Advanced Server V 2.1, Premium Edition. This leaves some place for pirates, and as a result, we do have pirate Linux in the market. However, the piracy issue is a little more complicated when it comes to Open Source Software, since no one owns the intellectual property and so it is hard to define what is piracy and what is not. Hence, more research is required in this direction.

More research is also needed in the field of software protection technologies for the Internet environment. It is true that not everyone who copies software today would buy it tomorrow if it were protected, and protection might put off a few potential customers. But, there is no doubt that in the vast majority of cases the investment in protection pays off handsomely in increased sales and profit. In the Internet era, detecting pirate software becomes easier, which give the software firms a great opportunity. However, the software firms have to make sure that if their actions will impact user's privacy and other rights before they search the web for pirates. This is a difficult issue, cause it not only involves technology, but also law and others. Hence, more attention should be paid to the study of this issue.

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