2002

Impact of Online Renting on Software Piracy

X. H. Zeng
National University of Singapore, zengxiao@comp.nus.edu.sg

Sang-Yong T. Lee
National University of Singapore, tlee@comp.nus.edu.sg

Hock-Hai TEO
National University of Singapore, teohh@comp.nus.edu.sg

IMPACT OF ONLINE RENTING ON SOFTWARE PIRACY

Zeng X. H. (zengxiao@comp.nus.edu.sg),

Lee, T. S. Y. (tlee@comp.nus.edu.sg), and

Teo H. H. (teohh@comp.nus.edu.sg).

ABSTRACT

Online rental of software is emerging as a new way of dissemination for several major software firms. Compared to outright selling, the renting scheme delivers the software as a service instead of a physical good. Hence, users cannot privately make copies for resale in the market. We investigate the impact of the renting mechanism on software piracy and pricing in a two-period model whereby a piracy market is present in the second period. We develop and compare models with or without renting. Our analysis shows that renting reduces social welfare but helps to increase a vendor's profit under certain conditions. We also assess the difference in outcomes in the presence of network effect.

1. INTRODUCTION

Online rental of software is increasingly being practiced by some major software companies. For instance, since 1996, Microsoft has launched the electronic distribution framework, which allows the consumers to pay a monthly fee for accessing the software over Internet. Recently, Microsoft even rented its office suite online, allowing people to use Microsoft Word, Excel and PowerPoint on a lease agreement. Another example is the application service provider model (ASP), which provides access to enterprise applications via the network (see, Delaney 1999). Several technologies such as Citrix and Internet2, are emerging to enable remote delivery of software to end users in a scalable and reliable fashion.

A distinguishing feature about the online rental mechanism is that the software is installed on vendors' servers instead of end-users' desktop. Vendors can use monitoring software to ensure no 'leakage' outside of the lease agreement. Compared to outright selling, vendors could alleviate the problem of end-user piracy (private copying) through this mechanism. Piracy has been a perennial problem since the advent of the software industry. Particularly, the emergence of Internet makes private copying even easier and cheaper. Software that are pirated include personal software to business application packages. Business Software Alliance reported $12 billion losses globally from piracy (BSA 1999). Moreover, infringement of intellectual property discourages the production of creative works. Governments of many countries have enacted compensatory laws to protect publishers and authors. For example, in the United States, software piracy is punishable by statutory damages of up to $100,000 for each work infringed and may result in a felony conviction.

We are interested in the impact of online renting on software piracy. In this paper, we treat software as a durable product that lasts for two periods, and consider private copying in the second period only. A two-period model has been previously used in studying traditional durable goods such as automobile and household appliances (Bulow 1982, Purohit 1999). We compare the vendor's pricing strategy and profit with or without renting option, and analyze the consequences for social welfare under each option. We also took into account the roles of government policy and network effect.

2. LITERATURE REVIEW

Economics of copying has attracted enormous attention from academics. Research on copying has focused mainly on its effects on producer's strategies and social welfare, and sometimes under conditions of network effect. The research stream on producers' sales and profit identified two main effects (Varian 2000). First, piracy will directly reduce demand of legitimate products. Second, originals are more valuable when copying is possible. Most argued that the relative cost of producing originals and copies is a key determinant in the change of profit. Particularly, profit will decrease when private copying is costly (e.g., Liebowitz 1985). These results were obtained under the assumption that the producer can price discriminate to capture the values of the copies made from each original. In response to piracy, producers could re-examine their decision on production quality level (Waldman 1984), extent of protection (Conner 1991), and optimal pricing (Fernando 1988).

The second research stream focused on social welfare and optimal government policy. Generally, this impact is complex. Producers are believed to under-produce in the presence of copying. Improving copyright protection might encourage producers to raise production but might induce greater social welfare loss due to underutilization (Waldman 1984). Besen et al. (1989) summarized the impact on producer and consumer welfare under different assumptions: (1) the extent to which the producer can appropriate the consumer surplus; and (2) the substitutability of copies compared to the original.

The third research stream examined impact on producers' strategies and social welfare when network effect is present. With network effect, the value of the product increases with the number of users. Software products tend to exhibit positive network effect. More users might help producers improve the product through greater feedback. Common use might also help enhance management techniques through standardization and foster higher product visibility. Copying might encourage legitimate sales when network effect is strong (Conner 1991) or diffusion of copying is faster (Muller 1995). A producer might deliberately facilitate copying to expand the installed base when there is competition (e.g., Shy 1999).

The recent emergence of online rental of software has also attracted some academic attention. Choudhary et al. (1998) discussed the benefits of renting in the presence of network externality. Gurnani et al. (2001) studied the actual usage behavior of consumers, and concluded that renting could expand the market size by tailoring the product to the needs of a particular client. However, most of the literature on online rental of software seems to neglect the existence of a piracy market. Additionally, little attention is being paid to understanding the link between private copying and the distribution mechanism.

This paper seeks to bridge the gap between the copying and the online rental literature by examining the effects of renting on software piracy. Specifically, we explore the following research questions: (i) Does renting help counter software piracy, and under what conditions? (ii) What is the optimal pricing strategy for the vendor when both selling and renting are used? (iii) How does renting affect social welfare? (iv) How do the outcomes change when network effect is present?

3. THE MODEL

We consider a software product market under a monopolist software vendor. It is a two period model. In the first period, the producer both sells and rents, and rental only lasts for one period. In the second period, producer sells and faces a copying market. We assume there is Bertrand competition in the piracy market, which drives the price to marginal cost. Following this typical assumption on information goods, marginal costs are zero in our model. (see Bakos et al.1998)

Following the market segmentation used in some previous studies (Conner 1991), we assume that there is a continuum of consumers indexed by the reservation price $h \in [0,1]$. Depending on the prices, consumers make the optimal decisions according to their preference. In the first period, consumer

decides whether to buy or rent or just stay out of the market. Consumers who buy in the first period do not need to do anything in the second period, while those who rent or stay out of the market would choose to buy the legal product, or to buy pirated copy or do nothing at all. If consumers choose to buy and use pirated copies, they may be caught and penalized later.

We define Ω_{b1} to be the software products sold to the consumers in the first period, Ω_r to be the products leased, Ω_{b2} to be the legal product sold in the second period, and Ω_c to be the pirated copies. Let p_{b1}, p_r, p_{b2} be the price for $\Omega_{b1}, \Omega_r, \Omega_{b2}$, respectively. Note that the price for Ω_c is zero. Let (x_1, x_2) be a consumer's choice, where $x_1 \in \{b, r, 0\}$ represents three choices in the first period – buying, renting, doing nothing, respectively; and $x_2 \in \{b, r, 0\}$ represents three choices in period two – buying Ω_{b2}, buying Ω_c, doing nothing, respectively.

To understand the software vendor's incentives to provide rental option to control software piracy, we compare two cases for the vendor: rental option versus no rental option. For each case, we first examine the consumer's choice and the corresponding surplus functions followed by deriving the demand function and the monopolist's profit.

3.1. WITHOUT RENTAL OPTION

In this case, the software provider only sells Ω_{b1} in the first period. Consumer decides whether to buy it or not. Non-buying consumers might buy Ω_{b2} or Ω_c or do nothing in the second period. Space for consumer's choices is represented by {(b, 0) (0, b) (0, c) (0, 0)}.

We examine the consumer surplus function for each group: (1) For consumer who chooses (b, 0), his surplus is $V_{(b,0)} = (1+\beta)h - p_{b1}$, where $\beta \in (0,1)$ is a discount factor. We assume that the surplus derived by consuming the product for one period is h, hence for two periods it is $(1+\beta)h$. (2) For consumer who first waits and then buys the legal product Ω_{b2}, his surplus would be $V_{(0,b)} = \beta(h - p_{b2})$. (3) For consumer who buys the pirated copy, his surplus would be $V_{(0,c)} = \beta(dh - f)$, where $d \in (0,1)$ measures the degree of substitutability between the pirated copies and the original since they might contain inconsistent/corrupt files or unresolved bugs. f is the expected value of fine, which is the probability for a pirated copy user to be caught multiplied by the government fine. We assume risk-neutral consumers. (4) For consumer who does nothing in both the periods, his surplus would be zero.

Consumers are then self-selected into different groups according to their reservation price for the product. Consumers are assumed to have unit demand. Denote the quantity for each group with Q. We can derive $Q_{(b,0)}$ by finding the marginal consumer who is indifferent between choosing (b, 0) and (0,b). Let h_1 be the reservation price for this marginal consumer. Since $V_{(b,0)} - V_{(0,b)}$ is increasing in h ($1+\beta \geq \beta \geq \beta d$), all consumers with $h > h_1$ would choose (b, 0) over (0,b). Therefore, $Q_{(b,0)}$ would be $1 - h_1$. Similarly we can derive other demand functions for (0,b), (0,c).

By solving $V_{(b,0)} = V_{(0,b)}$, $V_{(0,b)} = V_{(0,c)}, V_{(0,c)} = 0$ for h, we can get $h_1 = p_{b1} - \beta p_{b2}$, $h_2 = \frac{p_{b2} - f}{1-d}$ and $h_3 = \frac{f}{d}$. We have the following constraints $1 \geq h_1 \geq h_2 \geq h_3 \geq 0$. The demand function is

$Q_{(b,0)} = 1 - h_1$, $Q_{(0,b)} = h_1 - h_2$, and $Q_{(0,c)} = h_2 - h_3$. The monopolist software vendor will maximize the profit by setting discriminating prices for both of the periods, i.e., $\underset{(p_{b1}, p_{b2})}{Max}\pi = p_{b1}Q_{(b,0)} + \beta p_{b2}Q_{(0,b)}$ subject to $1 \geq h_1 \geq h_2 \geq h_3 \geq 0$.

By finding the first order condition with respect to p_{b1}, p_{b2}, we get $p_{b1}^* = \frac{1+\beta(1+f-d)}{2}, p_{b2}^* = \frac{1-d+f}{2}$, and the optimal demand for each segment are $Q_{(b,0)}^* = \frac{1}{2}, Q_{(0,b)}^* = \frac{f}{2(1-d)}, Q_{(0,c)}^* = \frac{1}{2} - \frac{f(2-d)}{2d(1-d)}$. And $\pi^* = \frac{1}{4} + \frac{\beta(1-d+f)^2}{4(1-d)}$.

It is showed that when $f = 0$ there is $Q_{(0,b)}^* = 0$, so that it is always optimal to sell only in the first period. Here, we have proposition 1.

Proposition 1: Government's penalty enables the producer to version his product for increased profitability.

Versioning leads to two results: on one hand, its lower price helps to expand the market by attracting some people from buying pirated copy to buying legal product; on the other hand, it cannibalizes sales of the superior product in the first period. It is showed that, when $f = 0$, the loss from cannibalization cannot be covered by the benefits gained from the expanded market, therefore product versioning is not optimal. When $f > 0$, the monopolist can differentiate the products more effectively. Particularly, we have $\frac{\partial Q_{(0,b)}^*}{\partial f} > 0$ and $\frac{\partial \pi^*}{\partial f} > 0$. When $f > \frac{d(1-d)}{2-d}$, $Q_{(0,c)}^* = 0$. Pirated copies will be completely driven out of the market.

3.2 WITH RENTAL OPTION

We assume that rental exists only in the first period (see Choudhary et al. 1998, Bulow et al. 1982). Rental is generally short-term in nature, and thus not considered in the second period. For consumers, they can either buy or rent or do nothing in the first period. Some people choose renting over buying since it is more affordable ($p_{b1} > p_r$) or they may just need the software for short-term usage. If he rents or does nothing, he might consider buying a legal software or a pirated copy in the second period. The surplus obtained from the rental product is $V_{(r,0)} = kh - p_r$, where $k \in (0,1)$ captures utility difference between the purchased copy and the rental copy. The rental mechanism might cause some inconvenience for users. Space for consumer's choices would be {(b, 0) (r, b) (r, c) (0, b) (r, 0) (0, c) (0, 0)}. The versions of products for these seven groups are sorted from the highest to the lowest given the condition that $k + \beta d > \beta > k > \beta d > 0$, which implies that consumers get more benefits by buying than by renting, and the rental products provide more benefits than the pirated copies. Though there are seven possible groups, they actually cannot exist simultaneously (Please see the proof in Appendix.A). We identified three cases:

Case 1: $0 < f \le \dfrac{d(k-\beta d)}{2k-\beta d}$

Market is segmented to four groups: (1) Buy at the beginning $V_{(b,0)} = (1+\beta)h - p_{b1}$; (2) Rent then buy $V_{(r,b)} = kh - p_r + \beta(h - p_{b2})$; (3) Rent and nothing $V_{(r,0)} = kh - p_r$; (4) Copy $V_{(0,c)} = \beta(dh - f)$.

Optimal solution for prices are $p_{b1}^* = \dfrac{1+\beta(1+f-d)}{2}$, $p_r^* = \dfrac{k+\beta(f-d)}{2}$, $p_{b2}^* = \dfrac{1}{2}$; quantity are $Q_{(b,0)}^* = \dfrac{1}{2}, Q_{(r,b)}^* = 0, Q_{(r,0)}^* = \dfrac{\beta f}{2(k-\beta d)}, Q_{(0,c)}^* = \dfrac{1}{2} - \dfrac{\beta f}{2(k-\beta d)} - \dfrac{f}{d}$; and profit is $\pi^* = \dfrac{1}{4} + \dfrac{\beta(1+f-d)}{4} + \dfrac{\beta f(k-\beta d+\beta f)}{4(k-\beta d)}$. It is optimal for the monopolist to sell and rent only in the first period and not to sell in the second period ($Q_{(r,b)}^* = 0$). Particularly, the constraints $1 \ge h_4 \ge h_5 \ge h_6 \ge h_7 \ge 0$ should not be violated. By submitting $(p_{b1}^*, p_r^*, p_{b2}^*)$, we have the condition $0 < f \le \dfrac{d(k-\beta d)}{2k-\beta d}$.

Case 2: $\dfrac{d(k-\beta d)}{2k-\beta d} < f \le \dfrac{d(1-d)}{2-d}$

The optimal solution is $p_{b1}^* = \dfrac{1+\beta(1+f-d)}{2}, p_r^* = \dfrac{k}{2}, p_{b2}^* = \dfrac{1-d+f}{2}$, the optimal quantity is $Q_{(b,0)}^* = \dfrac{1}{2}$, $Q_{(r,b)}^* = 0$, $Q_{(0,b)}^* = \dfrac{f}{2(1-d)}$, $Q_{(0,c)}^* = \dfrac{1}{2} - \dfrac{f(2-d)}{2d(1-d)}$, and profit is $\pi^* = \dfrac{1}{4} + \dfrac{\beta(1-d+f)^2}{4(1-d)}$. Since $Q_{(r,b)}^* = 0$, no renting option is best for the monopolist.

Case 3: $f = 0$

The optimal solution is $p_{b1}^* = \dfrac{1+\beta(1+f-d)}{2}, p_r^* = \dfrac{k}{2}, p_{b2}^* = \dfrac{1-d+f}{2}$, the optimal quantity is $Q_{(b,0)}^* = \dfrac{1}{2}, Q_{(r,b)}^* = Q_{(r,c)}^* = 0, Q_{(0,c)}^* = \dfrac{1}{2}$ and profit is $\pi^* = \dfrac{1+\beta(1+f-d)}{4}$. Again, when the government exacts no penalty, the optimal strategy for the monopolist is to provide only first period sales and without renting option.

3.3. COMPARISON

First, we investigate the impact of offering renting from the standpoint of the software vendor. We compare the profit π of the monopolist with or without renting option. For case 1,

$\pi^{*rent} - \pi^{*norent} = \frac{\beta f^2(\beta - k)}{4(k - \beta d)(1-d)} > 0$. And, in cases 2 and 3, profit does not change since it is optimal not to offer rental products.

Proposition 2: The software vendor can increase the profit by offering the rental option only if the government penalty satisfies $0 < f \le \frac{d(k-\beta d)}{2k-\beta d}$.

When $f \ge \frac{d(k-\beta d)}{2k-\beta d}$, the penalty is high enough to drive out copying; therefore no renting is needed. When $f = 0$, no renting will change the market share of pirated copies. When f is in the intermediate range, by introducing a lower version ($k \le \beta \le 1$) product -- the rental product, the monopolist expands its market size substantially, attracting not only the consumers who originally buy at the second period but also some consumers who would buy the pirated copy. Revenues from renting exceed the losses from selling in the second period: $p_r^{*rent} Q_{(r,0)}^{*rent} - \beta p_{b2}^{*norent} Q_{(0,b)}^{*norent} = \frac{\beta f^2(\beta - k)}{4(k - \beta d)(1-d)} > 0$.

Proposition 3: When $0 < f \le \frac{d(k-\beta d)}{2k-\beta d}$***, renting helps more when the penalty is higher and the pirated copies approximating closer to the original, that is,*** $\frac{\partial(\pi^{*rent} - \pi^{*norent})}{\partial d} > 0$ ***and*** $\frac{\partial(\pi^{*rent} - \pi^{*norent})}{\partial f} > 0$.

The intuition behind is that, when quality of pirated copies is good, the vendor has more incentives to offer the renting option to compete against them. Since the higher penalty allows the vendor to price discriminate more effectively, the advantage brought by renting becomes obvious.

Proposition 4: When $0 \le f \le \frac{d(1-d)}{2-d}$***, the higher the substitutability of pirated copies or rental products, the lower the profit of monopolist (*** $\frac{\partial \pi^{*rent}}{\partial d} < 0, \frac{\partial \pi^{*rent}}{\partial k} < 0$***); and the higher the penalty by government, the higher the profit of monopolist (*** $\frac{\partial \pi^{*rent}}{\partial f} > 0$***).***

The first two terms are obvious. When the substitutability of the pirated copies is higher, there is more competition from the copying market, which reduces the sales of legitimate product more. As the government penalty increases the cost of pirated copies, making them less attractive, the provider's loss due to piracy is greatly reduced. The last term means that the version of rental products should not be too high since it will cannibalize the sales in the first period. Suppose the condition $k > \beta d$ holds, the optimal version of rental products should be close to the version of the pirated copies.

Next, we investigate the impact of renting on social welfare. Following the utilitarian approach by Waldman (1991), social welfare is the sum of the surplus of consumers, the profit of vendor, and the fine collected by government. We denote the welfare without renting and case 1 with renting with $W^{*norent}, W^{*rent}$, respectively. Then there is:

$$W^{*norent} = \frac{3+\beta(3+d+2f)}{8} - \frac{\beta f^2(4-3d)}{8d(1-d)} \quad W^{*rent} = \frac{3+\beta(3+d+2f)}{8} - \frac{\beta f^2(4k-3\beta d)}{8d(k-\beta d)}$$

Proposition 5: Introduction of renting will result in the loss of social welfare. That is, $W^{*rent} - W^{*norent} = -\frac{\beta f^2(\beta - k)}{8(1-d)(k-\beta d)} < 0$.

This is due to the underutilization of the lower version of the rental product. When the rental option is introduced, buying consumers in period two would switch to renting. Since this rental product has a lower version, the consumer surplus is reduced.

Proposition 6: The higher the substitutability of pirated copies or rental products, the higher the social welfare. ($\frac{\partial W^{*rent}}{\partial d} > 0$, $\frac{\partial W^{*rent}}{\partial k} > 0$***)***

Since the higher version of products provides higher utility for consumers, both increasing the version of pirated copies and the rental products would benefit the consumers. Therefore, for societal sake, software vendors should be encouraged to produce a higher version of the product, say, by improving the service in renting. However, we know from the previous result (proposition 4) that the vendor is worse off in this way.

Proposition 7: To maximize social welfare, the optimal penalty by government is $f^* = 0$.

From proposition 5, we know that renting always results in a social loss. Therefore, renting should not be offered for the benefit of society. Since the penalty just prevents people from using the pirated copy, it is optimal not to set any penalty. For the case with renting option, we found that the second optimal solution $f^* = \frac{(k-\beta d)d}{4k-3\beta d}$. It shows that the penalty should neither be too high nor too low. Government can strike a balance between public benefit and the financial incentives of vendor.

4. MODEL WITH NETWORK EFFECT

Further, we examine the case when network effect is presented. When there is network effect, the greater the number of users, and the higher the value of software product. If a consumer buys Ω_{b1} and uses it over two periods, his surplus would be $V_{(b,0)} = (1+\beta)h - p_{b1} + eQ_I + \beta e(Q_I + Q_{II})$, where e is the intensity of network effect and Q_I, Q_{II} are the numbers of copies used in the first period and in the second period, separately. Here, we assume that the first period purchaser can get upgrades, thus enjoying the network benefit in the second period ($\beta e(Q_I + Q_{II})$). Note that in the no renting case Q_I is the number of purchasers in the first period while in the renting case it is the number of

purchasers plus the number of renters. If consumer rents Ω_r, his surplus would be $V_{(r,0)} = kh - p_r + eQ_I$. If consumer buys Ω_{b2} in the second period, his surplus would be $V_{(0,b)} = \beta(h - p_{b2}) + \beta e(Q_I + Q_{II})$. If consumer buys the pirated copy Ω_c, his surplus would be $V_{(0,c)} = \beta(dh - f) + \beta e(Q_I + Q_{II})$.

4.1. COMPARISON

We compare the models with renting or without renting through simulation analyses. We would focus on the impact of the network effect on optimal pricing, quantity and profit by arbitrarily setting and changing the values of parameters in the model. We show the simulation results when $\beta = 0.9, d = 0.8, k = 0.8, f = 0.05$ in Appendix B. Other parameter values bring only quantitative differences. From our simulation results, we can conclude the following propositions.

Proposition 8: The profit and social welfare are increasing with the intensity of network effect in both of the case with renting and without renting.

The network effect raises the utility of the consumers and hence the willingness to pay. Therefore, both the software vendor and the consumers are better off.

Proposition 9: In the presence of network effect, the software vendor's profit is higher when offering renting option.

Introduction of renting in the first period magnifies the network effect thus allow the product to be sold at a higher price ($p_{b1}^{*rent} \geq p_{b1}^{*norent}$, $p_{b2}^{*rent} \geq p_{b2}^{*norent}$). The software vendor can effectively differentiate the market by selling to the high-type consumers in the first period and leasing then selling to the residual consumers. More people would transfer from buying pirated copy to buying or renting the legal product in the first period to enjoy the benefit from network effect (eQ_I). When e is high enough, the copying market is totally driven out.

Proposition 10: With renting option, social welfare is only higher when the network effect is in the middle range.

Renting has two-sided effects on social welfare. On one hand, it raises the social welfare since renting is more affordable thus allowing more people to use it. On the other hand, the lower version reduces the social welfare due to underutilization. Our simulation results show that, when the network effect is at the middle level, the benefit from renting by expanding the market size can outweigh the loss from providing the lower version. However, when the network effect is low, or high enough until the whole market is covered, it would be best for the society not to use the renting option.

5. FUTURE RESEARCH EXTENSIONS

The main focus of this paper is to show that renting is a viable strategy in countering the threat of piracy. Vendor's profit increased with the use of a renting option. We show that, with the introduction of renting, some consumers switch from copying to renting, and the software vendor is better off renting. However, introduction of renting leads to the loss of social welfare. We show the necessary optimal government policy to strike a balance between the vendor and the society. We also extended

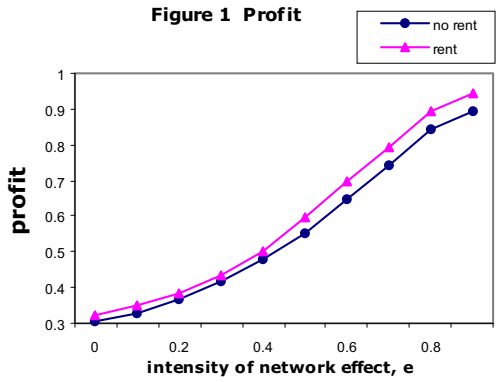
the model to the case when network effect is present. In this paper, we assume that a monopolist both sells and rents the product. Sometimes, the software manufacturer has to rely on intermediaries to distribute the product, i.e. a seller and a renter. Further research to investigate the optimal strategies under different market structures should be pursued. Additionally, we only consider the monopolist in the model. The model can be extended to a duopoly or oligopoly situation in future efforts.

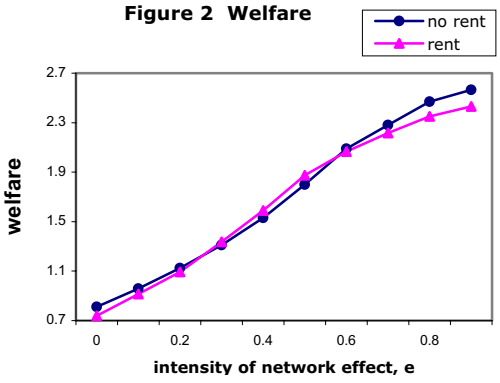
APPENDIX A

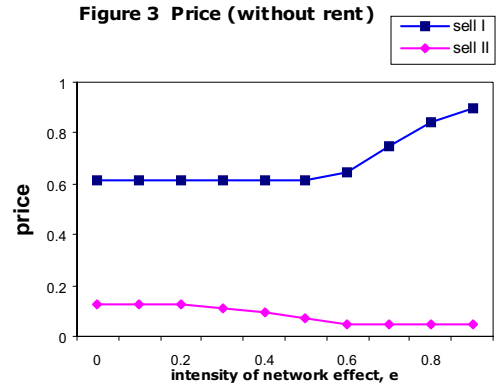
Proof of market segmentation

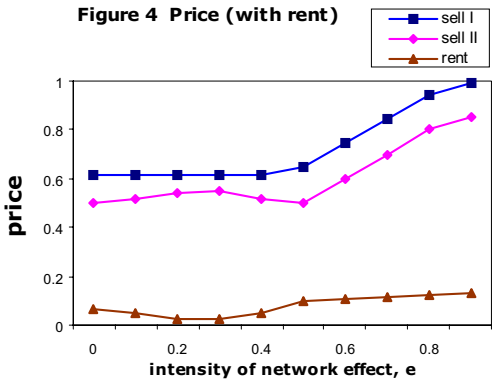
Proof for case 1: when (r, 0) exists, (0,b) will be dominated, and only one of the two groups (r, c), (0,c) can exist. (1) If (r, 0) exist, there should be such h_0 that $V_{(r,0)}(h_0) > 0$ and $V_{(r,0)}(h_0) > V_{(0,b)}(h_0)$, which derive $\frac{p_r}{k} \le \frac{\beta p_{b2} - p_r}{\beta - k} \Rightarrow p_r \le p_{b2} k$. Then, for any $h < \frac{p_r}{k} < p_{b2}$, there is $V_{(0,b)} < 0$, and for $h \ge \frac{p_r}{k}$, there is $V_{(r,b)} > V_{(0,b)}$, so that (0, b) cannot be chosen. (2) If both (r, c) and (0,c) exist, for people to choose copying, there should be such h_0 that $V_{(0.c)}(h_0) > 0$, $V_{(0,c)}(h_0) > V_{(r,0)}(h_0)$, which derive $\frac{f}{d} \le \frac{p_r - \beta f}{k - \beta d} \Rightarrow \frac{f}{d} \le \frac{p_r}{k}$. However, for any $h < \frac{p_r}{k}$, there is $V_{(0,r)} < 0$, and for $h \ge \frac{p_r}{k} \ge \frac{f}{d}$, there is $V_{(r,c)} > V_{(r,0)}$, so that (r, 0) would not be chosen, which contradict with the assumption <Q.E.D>. Similarly, we can prove the market segmentation for cases 2 and 3.

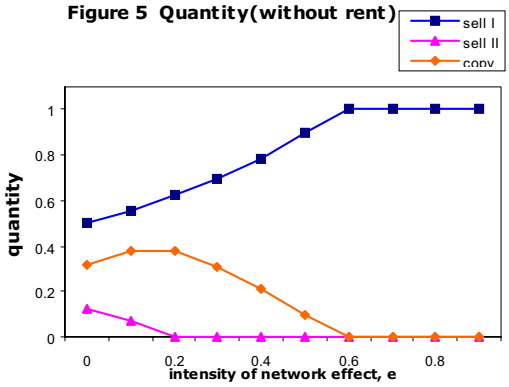
APPENDIX B - *Simulation results* ($\beta = 0.9, d = 0.8, k = 0.8, f = 0.05$)

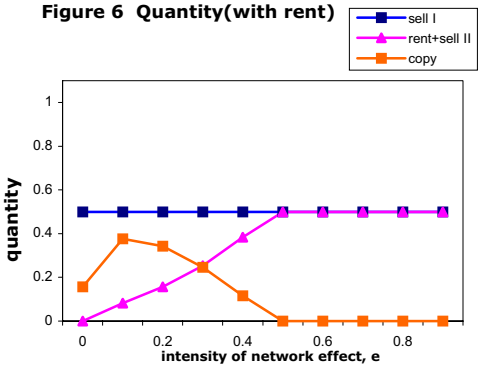












REFERENCES

Bakos, J., Brynjolfsson, E. and Lichtman, D. (1998). Shared information goods. *Tech. Rep., MIT. http://ccs.mit.edu/erik*

Besen, S. M. and Kirby, S. N. (1989). Private copying, appropriability and optimal copying royalties. *Journal of Law and Economics*, 32(2), 255-280.

Bulow, J.I. (1982). Durable-goods monopolists. *The Journal of Political Economy*, 90(2), 314-332.

Business Software Alliance. 1999 Global Software Piracy Report
http://www.bsa.org/usa/globallib/piracy/piracystats99.phtml

Conner, K. R., and R. P. Rumelt (1991). Software piracy: an analysis of protection strategies. *Management Science*, 37(2), 125-139.

Choudhary, V., Tomak, K. and Chaturvedi, A. (1998). Effect of network externalities on software pricing. *IEEE Press*, 251-260.

Delaney, K. J. (1999). Business technology vendors phase out flat-rate pricing. *Wall Street Journal*, August 13.

Fernando, N. (1988). Optimal strategic pricing of reproducible consumer product. *Management Science*, 34(8), 921-937.

Givon, M., Mahajan, V., Muller, E., Jan (1995). Software piracy: estimation of lost sales and the impact on software diffusion. *Journal of Marketing*, 59(1), 29-37.

Gurnani, H. and Karlapalern, K. (2001). Optimal pricing strategies for Internet-based software dissemination. *Journal of the Operational Research Society*, 52(1), 64-70.

Liebowitz, S.J. (1985). Copying and indirect appropriability: photocopying of journals. *Journal of Political Economy*, 93(5), 945-957.

Shy, O. (1999). A strategic approach to software protection. *Journal of Economics & Management Strategy*, 8(2), 169-190.

Takeyama, L.N. (1994). The welfare implications of unauthorized reproduction of intellectual property in the presence of network externalities. *Journal of Industrial Economics*, 42(2), 155-166.

US copyright office homepage: http://www.loc.gov/copyright/

Varian, H. (2000). Buying, sharing, and renting information goods. *The Journal of Industrial Economics*, 48(4), 473-488.

Waldman, M. (1984). The effects of increased copyright protection: an analytic approach. *The Journal of Political Economy*, 92(2), 236-246.

Wilcox, J. and Farmer M. A. (2000). Microsoft gives details of software-for-rent strategy.
http://digitalcity.cnet.com/news/0-1003-200-2256341.html?tag=mainstry