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Software Piracy in the Video Game Market

by

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Software Piracy in the Video Games Market*

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Abstract

In this paper, the market for video games is considered, where some firms produce both, hardware and software. It is analyzed, whether these firms are interested in strategically enabling software piracy. It will be shown that this is indeed the case, if firms differ substantially in hardware production costs. Then, the low-cost producer gains from enabling software piracy in two ways. First, it increases its market share in the hardware and, accordingly, in the software market. Second, it can raise its hardware price. These two benefits overcompensate the loss resulting from a higher fraction of pirating consumers in the software market.

Key words: Video Games Market, Software Piracy, Fundamental Transformation

JEL classification: D21, L13, L86

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1 Introduction

Until 1994, the market for video games was dominated by the Nintendo corporation. Then, however, Sony entered the market with its Playstation 1 console. Soon, the Playstation 1 became far more popular than Nintendo's console N64 and Sony replaced Nintendo as the dominating firm in the video games market. Today, Sony is still the market leader in spite of aggressive market entry strategies by e.g. Microsoft.

It is interesting to compare Sony's Playstation 1 with Nintendo's N64, as competition between these consoles has triggered an extreme market change. The most remarkable difference is that games for the Playstation are stored on CDs, while N64 games are stored on cartridges.¹ CDs have the advantage that their production costs are lower. Cartridges, on the other hand, cannot be duplicated easily so that software piracy is only an issue for CDs. Although, at first sight, this seems to be a disadvantage of CDs, it is often argued that the wide availability of duplicated software was a major factor for Playstation's success in the market. To see this, consider the following statements taken from user forums of popular computer websites:²

¹Due to different storing mediums, it is clear that software produced for the Playstation 1 is incompatible with the N64 and vice versa. Note, however, that this is also the case for consoles using the same storing medium. Therefore, there is some kind of *fundamental transformation* in the video games market. Having purchased the video games console of a certain producer, a consumer is restricted to buy software compatible with the console.

²The first two statements are taken from the Microsoft X-box user forum, the third is from the slashdot user forum.

Note that a so called Mod-Chip has to be installed in the console in order to make duplicated software compatible with the Playstation (hence the word "modded" in the second statement). The original aim of this Chip is to make the Playstation compatible with imported software. Thus, a Mod-Chip can be legally installed in every video games shop.

"All my friends had copied PS1 games, I had 300 copied games, markets were full of copied PS1 games. PS1 made its name from copied games."

"While I am not from Japan, I am from Asia and where I am from I can definitively say that nearly 80% of all console units in this place are modded and play pirated games. And in Asia, the Playstation is king for several reasons. The success of the Playstation 2 rode on the success of the Playstation 1. And the PS1 is one of the widely pirated consoles in Asia. Games back then cost around \$1, and that was cheap."

"Absolutely, why did the Sony Playstation crush the N64? Because you can copy easily for the Playstation."

The idea that Playstation's success may partly stem from the possibility of playing duplicated software raises the suspicion that hardware producers in the video games market may strategically reduce copy protection levels.³ This suspicion is analyzed in the current paper. We consider four firms that are allocated on the Salop circle. Two of these firms produce both, video games hardware and software. The remaining two firms specialize in software production.⁴ The hardware producers are assumed to be heterogeneous in that they have different hardware production costs. It will be shown that, if this heterogeneity is sufficiently strong, the low-cost producer strategically enables software piracy. In this way, it increases its market share in the hardware and, accordingly, in the software market. Moreover, as a consequence of the reduced copy protection it is able to raise its hardware price. These two benefits overcompensate the loss resulting from a higher fraction of pirating

³In this paper, we use the terms "enabling of piracy" and "reduction of copy protection levels" as synonyms.

⁴Note that this is indeed an appropriate description of the video games market. Hardware producers are also active in the market for software. Further, there are other firms that are active in the software, but not in the hardware market.

consumers in the software market.

It is worth emphasizing that there exist further markets to which the model nicely applies. Consider e.g. the market for events. An organizer of an event realizes profits through two channels, ticket sale and catering. In most arenas, some snack bars or restaurants are run by the organizer, while others are run by private people. A consumer who expects to eat and drink something, while attending the event, will be less willing to buy a ticket, if food is rather expensive. Similarly to the reasoning for the video games market, the organizer might then allow consumers to bring their own food to the event in order to attract more visitors and increase ticket prices.

The paper is organized as follows: The next section briefly presents and discusses related literature. In Section 3, the model is described, while it is solved in Section 4. Finally, Section 5 concludes.

2 Related Literature

There already exists a number of papers on product piracy, which can be roughly divided into four categories.⁵ A first strand of the literature (see e.g. Hurt & Schuchman (1966), Novos & Waldman (1984), Johnson (1985), Belleflamme (2003) or Burton et al. (2005)) argues that higher product piracy leads to lower profits of the firms, whose products are duplicated. Moreover, this decrease in profits yields lower (ex ante) incentives for firms to invest in product development, for piracy of the products reduces the gains from these investments. This means that piracy may seriously harm the welfare of a society.

In contrast, the papers of Liebowitz (1985), Besen (1986), Besen & Kirby

⁵For a survey see Peitz & Waelbroeck (2003).

(1989), Bakos et al. (1999) and Varian (2000) point to a potential benefit of product piracy. This benefit is based on the assumption that book or video producing firms may indirectly appropriate revenues from users who are not original purchasers. As, in these markets, libraries and video stores are oftentimes the starting point of copying activities, firms indirectly appropriate revenues by charging these institutions higher prices. By setting the prices appropriately, firms may indeed achieve higher profits than in a setting, where copying is not possible.

Further, there is some literature (see, for example, Connor & Rumelt (1991), Takeyama (1994), Shy & Thisse (1999), Gayer & Shy (2003) or Peitz (2004)) analyzing the role of product piracy in the presence of network effects. Their main reasoning is the following: If the value of a certain product increases in the number of (legal and illegal) users, product piracy might be useful, for it leads to a higher dispersion of the product and, therefore, to an increase in product value. This increase in product value may again yield higher profits describing a second benefit from product piracy.

Finally, the paper by Peitz & Waelbroeck (2006) stresses the role of sampling in the music industry. It is argued that by listening to pirated music, a consumer receives information concerning the match between the music's characteristics and his own taste. If a copy is only an imperfect substitute for the original, the consumer may then be willing to pay more for the latter, which, in turn, may lead to a higher profit.

Two remarks are necessary: First, note that previous work has not considered the market for video games. In other markets, where product piracy is an issue, the results to be derived in this paper do not apply. This is either because hardware producing firms are not active in the software market (e.g. software produced for personal computers) or because software is also

compatible with hardware of different producers (e.g. Music-CDs and Film-DVDs). Second, indirect appropriability, network effects and sampling may also play a role in the video games market. Yet, in order to highlight the strategic effects that are only present in the video games market, we abstract from these considerations.

3 Description of the model and notation

Consider a situation with four firms (indexed by $i = 1, \dots, 4$). Firms 1 and 2 are active in both, the market for video games hardware and software. Firms 3 and 4, on the other hand, are only active in the software market. Let k_1 (k_2) denote the price firm 1 (firm 2) demands for its hardware, while p_i stands for the respective software price. Software produced by firms 1 and 4 is supposed to be usable only on firm 1's hardware. Similarly, firms 2 and 3 produce software that can only be used in combination with firm 2's hardware.⁶ For simplicity and with only little loss of generality, production of software occurs at zero cost. Hardware production, on the other hand, leads to costs which are given by $C_1 = c_1x_1$ and $C_2 = c_2x_2$, with $c_1 \neq c_2$ as respective per-unit costs ($c_1, c_2 \geq 0$) and x_1, x_2 as the respective amount of hardware produced by the firms. Consumers attach no value to hardware per se, but they value software. In this context, consumers are supposed to differ in tastes for the respective firms' products. Each firm produces a different

⁶Note that we do not endogenize the platform choices of the firms specializing in software production. In principle, a reduction in copy protection levels of a hardware producer may lead to a switch from the software firms to another hardware producer. This may hurt the hardware producer, in case consumers will be more willing to purchase a certain video games console, if many games for this console are available. We revisit this point and partly invalidate this argumentation in Section 5.

video game and each video game is preferred by some consumers. To capture this formally, we follow the modeling approach by Salop (1979) and assume that consumers are uniformly distributed on a circle with a perimeter equal to 1, with total consumer mass normalized to 1. The four firms are located on this circle as shown in Figure 1.⁷ The distance between firms 1 and 4 (and 2 and 3) is $b \in (0, \frac{1}{2})$, while distance between firms 1 and 2 (and 3 and 4) is $0.5 - b$. We take the firms' locations as exogenously given. The value a consumer attaches to a video game is given by $v - td^2$. v denotes the value a consumer attaches to a product that exactly meets his taste, d is the distance⁸ between the consumer's and the firm's location measured along the circle and t is a factor indicating how strongly product value decreases with distance from the firm. The assumption that valuation depends on quadratic distance is introduced to avoid problems with equilibrium existence.⁹ Each consumer underlies some time constraint. This means that he has just enough time to play one single video game. Thus, if a consumer has acquired a game, he will never buy a second one.

It is assumed that consumers firstly decide on their hardware purchases. Thereafter, sale of software occurs. As mentioned before, purchase of hardware leads to some kind of fundamental transformation: Before a consumer buys hardware, he may choose between four different software games. Thereafter, he has only two different games available, as the remaining two games are incompatible with his hardware. Similarly, in the hardware market, firms compete for all consumers, while, in the software market, competition is re-

⁷Note that the results to be derived in this paper will not change, if we exchange the locations of firms 1 and 4 and/or firms 2 and 3.

⁸Note that "distance" should not be taken literally. It acts as a metaphor, indicating, how much a firm's product differs from the consumer's most preferred product.

⁹See, for example, D'Aspremont et al. (1979) or Economides (1986).

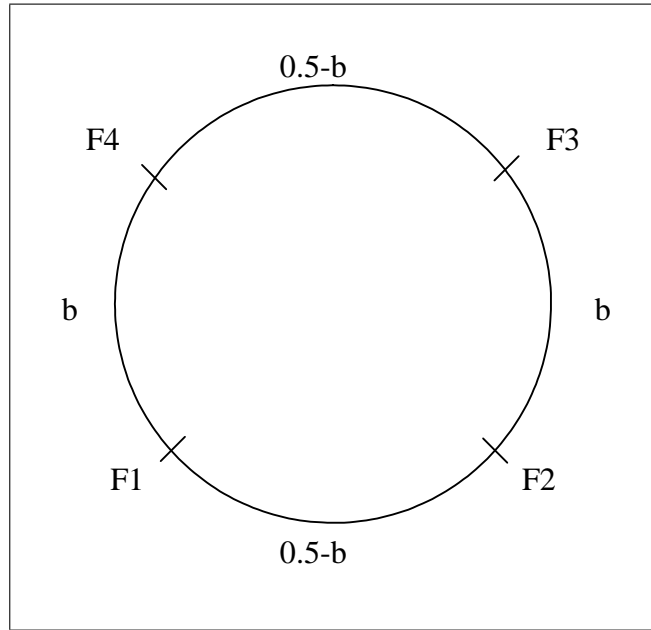


Figure 1: Locations of the four firms

stricted to the consumers who bought appropriate hardware.

Consumers are supposed to know, which games become available for each console, when deciding about their hardware purchases. Nevertheless, we assume that bundling of hardware and software by the hardware firms is impossible. Taken together, these two assumptions could reflect the fact that, in practice, hardware purchases often take place, when some games are already presented at e.g. exhibitions or in video games magazines, but cannot be purchased until some later date.

In the software market, firms are threatened by piracy. We model this by assuming that, with probability q_1 (q_2), a consumer may receive costless copies (which are perfect substitutes for the respective original) of all games compatible with the hardware of firm 1 (2). As a consumer receives no extra utility from possessing a second game, he will, in case copies compatible

with the hardware are available, always copy his most preferred game and be indifferent between receiving a copy of the other game or not. q_1 and q_2 are supposed to be decision variables of the hardware producing firms. Each firm can design its hardware in a way that enables more or less copying. To focus on the strategic effects of software piracy, changing q_1 or q_2 is assumed to be at no cost for the firms. Further, the parameters q_1 and q_2 can be observed by all parties. That is, each firm and each consumer knows the respective parameter choices.

This approach to introduce copying into the model is admittedly a very simplified one. There are two justifying reasons. First, the important effect of copying in this model is that a consumer's expected cost for acquisition of software declines. This effect, however, is also present in more sophisticated models of copying as e.g. Novos & Waldman (1984) or Connor & Rumelt (1991). Second, the model will simply be no longer tractable, if we model copying in a more complex way.

The timing of the model is as follows: At date 1, the hardware producers decide on q_1 and q_2 , while, thereafter, they determine the hardware prices. The two firms act simultaneously, respectively, i.e., no firm has a first-mover advantage. At date 3, consumers decide on their hardware purchases. The software producers determine the software prices at date 4. At date 5, nature decides on whether copies of the games become available. Finally, at date 6, consumers decide on whether or not to buy software, and, in the former case, on whose software to buy. We combine dates 1 to 3 to a stage 1, where the hardware market is considered, and dates 4 to 6 to a stage 2, which deals with choices associated with the software market.

4 Solution to the model

4.1 The software market

To analyze the effect of software piracy on competition between the hardware producers, we assume that the market is completely covered. In other words, in equilibrium, each consumer decides to buy hardware and software (if copies are unavailable). This is the natural outcome, if v is sufficiently large compared to t . We work backwards and start at stage 2 of the model, i.e. we first consider the software market. Note that costs for hardware acquisition are sunk and, thus, do not affect decisions at this stage. At dates 4 to 6, we usually consider two independent software markets. The first (second) consists of those consumers who have acquired firm 1(2)'s hardware. Let $|a|$ denote the distance between the indifferent hardware buyer and firm 1's location. Then, the size of the first software market is $b + 2a$, while the size of the second market is $1 - b - 2a$.¹⁰ It is sufficient to analyze firm and consumer behavior on the first software market. The solution for the second market is analogous. As noted before, consumers differ in their valuations for the two firms' products, i.e. we are in a setting with product differentiation. Consumers that have acquired the hardware of firm 1 and, hence, purchase software from either firm 1 or firm 4 are, as shown in Figure 2 for $a > 0$, uniformly distributed on a line segment of length $b + 2a$.¹¹ Firm 1's distance from the left end equals firm 4's distance from the right end and is given by a . Denote by z a consumer's distance from the left end of the line segment. Such a consumer has net utility $u_{1s} = v - p_1 - t(z - a)^2$, if buying software from firm 1 and $u_{4s} = v - p_4 - t(z - b - a)^2$, if buying from firm 4. Hence,

¹⁰Note that a need not be positive.

¹¹Competition in the software market is therefore analogous to Hotelling's model (1929) of the "linear city".

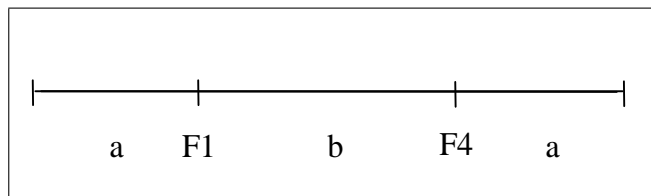


Figure 2: Locations of the two firms in the first software market

for the indifferent consumer the following condition must hold

$$v - p_1 - t(z - a)^2 = v - p_4 - t(z - b - a)^2 \iff z = \frac{1}{2bt} (p_4 - p_1 + bt(2a + b)) \quad (1)$$

Thus, z denotes the relative amount of consumers (of population size 1) who want to acquire software from firm 1. Each consumer copies his preferred product with probability q_1 . As a result, the two firms' second-stage profits are given by

$$\pi_{12} = p_1 \frac{1}{2bt} (p_4 - p_1 + bt(2a + b)) (1 - q_1) \quad (2)$$

$$\pi_{42} = p_4 \frac{1}{2bt} (p_1 - p_4 + bt(2a + b)) (1 - q_1) \quad (3)$$

Maximizing these profits leads to a symmetric solution, i.e., both firms choose the same prize $p_1 = p_4 =: p = bt(2a + b)$.¹² Inserting this price into (2) and (3), respectively, yields the optimal profits, which are given by $\pi_{12} = \pi_{42} = \frac{t}{2} (1 - q_1) b(2a + b)^2$. One can easily see that these profits are decreasing in q_1 . This is very intuitive. The higher the probability of copying, the smaller is the number of consumers who actually pay for a product and the smaller are profits. Further, we get the well-known results that profits are higher, the stronger product value decreases with distance and the bigger the market.

¹²Notice that here, as well as in all maximization problems that follow, the second-order conditions are satisfied.

4.2 The hardware market

Let us now turn to stage 1 of the model, where consumers decide on their hardware purchases. Divide the circle horizontally into two halves and consider a consumer being located in the lower half. Such a consumer will, at the model's second stage, buy software from either firm 1 or firm 2.¹³ Let y denote his distance from the left end of the lower half of the circle. His net utilities, if buying from firm 1 (2), are then given by $u_{1h} = v - k_1 - (1 - q_1)bt(2a + b) - t(y - 0.5b)^2$ ($u_{2h} = v - k_2 - (1 - q_2)bt(1 - b - 2a) - t(0.5 - 0.5b - y)^2$). The net utility consists of gross utility ($v - t(y - 0.5b)^2$ or $v - t(0.5 - 0.5b - y)^2$) from playing the video game minus expected costs for hardware (k_1 or k_2) and software ($(1 - q_1)bt(2a + b)$ or $(1 - q_2)bt(1 - b - 2a)$) acquisition. For the indifferent consumer, u_{1h} must equal u_{2h} . We thus have the following condition:¹⁴

$$a = \frac{t - 4b^2t + 4(k_2 - k_1) - 4btq_2(1 - b) + 4b^2tq_1}{4t + 8bt - 8bt(q_1 + q_2)} \quad (4)$$

Recall that the demand for firm 1's (firm 2's) hardware equals $b + 2a(1 - b - 2a)$, which can be rewritten as $\frac{2bt + t + 4(k_2 - k_1) - 4btq_2}{2t + 4bt - 4bt(q_1 + q_2)}$ ($\frac{2bt + t + 4(k_1 - k_2) - 4btq_1}{2t + 4bt - 4bt(q_1 + q_2)}$).

It is easy to see that the demand for either firm's product increases, if, for fixed hardware prices, the own copy protection is reduced or the opponent's copy protection is increased.¹⁵ Hence, for fixed hardware prices, the optimal level of copy protection would be determined by trading off two countervailing effects. On the one hand, reducing copy protection yields a higher market

¹³This is a consequence of the second-stage solution's symmetry.

¹⁴Note that, for the indifferent consumer, $y = 0.5b + a$.

¹⁵Note that for the argumentation to hold, the two numerators $2bt + t + 4(k_2 - k_1) - 4btq_2$ and $2bt + t + 4(k_1 - k_2) - 4btq_1$ must be positive. Otherwise, hardware prices would be so different that one firm covers the whole market. In this case, the firm would not benefit from reducing copy protection. In the proof of Proposition 1, we provide specific conditions for each firm having a strictly positive market share.

share and, accordingly, a higher profit. On the other hand, it is costly, too, since less consumers buy software instead of copying it. In order to see, whether these effects are still decisive, if hardware prices are endogenized, we turn to a derivation of the prices. Each firm maximizes its overall profit (that is, the sum of the profits from hardware and software sale). These overall profits are given by

$$\begin{aligned} \pi_1 = & (k_1 - c_1) \left(\frac{2bt + t + 4(k_2 - k_1) - 4btq_2}{2t + 4bt - 4bt(q_1 + q_2)} \right) \\ & + \frac{(1 - q_1)bt}{2} \left(\frac{2bt + t + 4(k_2 - k_1) - 4btq_2}{2t + 4bt - 4bt(q_1 + q_2)} \right)^2 \end{aligned} \quad (5)$$

$$\begin{aligned} \pi_2 = & (k_2 - c_2) \left(\frac{2bt + t + 4(k_1 - k_2) - 4btq_1}{2t + 4bt - 4bt(q_1 + q_2)} \right) \\ & + \frac{(1 - q_2)bt}{2} \left(\frac{2bt + t + 4(k_1 - k_2) - 4btq_1}{2t + 4bt - 4bt(q_1 + q_2)} \right)^2 \end{aligned} \quad (6)$$

Determining the first-order conditions and solving them simultaneously yields the following expressions for the optimal hardware prices:

$$\begin{aligned} k_1 = & \frac{8(1 + b - 2bq_1 - bq_2)c_1}{8b - 16b(q_1 + q_2) + 12} \\ & + \frac{(1 - 2bq_2)(4c_2 + 2bt + 3t - 4bt(q_1 + q_2))}{8b - 16b(q_1 + q_2) + 12} \end{aligned} \quad (7)$$

$$\begin{aligned} k_2 = & \frac{8(1 + b - 2bq_2 - bq_1)c_2}{8b - 16b(q_1 + q_2) + 12} \\ & + \frac{(1 - 2bq_1)(4c_1 + 2bt + 3t - 4bt(q_1 + q_2))}{8b - 16b(q_1 + q_2) + 12} \end{aligned} \quad (8)$$

It is helpful to take a closer look at these prices. In particular, it is interesting to see, how the prices depend on q_1 and q_2 . The following Lemma provides corresponding results:

Lemma 1 (i) k_1 (k_2) is increasing in q_1 (q_2), if and only if $c_2 > c_1$ ($c_1 > c_2$).
(ii) If $c_1 - c_2$ ($c_2 - c_1$) is not too large, k_1 (k_2) is decreasing in q_2 (q_1).

Proof. Let us first consider the derivative $\frac{\partial k_1}{\partial q_1}$. This derivative is equal to

$$\begin{aligned} \frac{\partial k_1}{\partial q_1} &= \frac{(-16bc_1 - 4bt(1 - 2bq_2))}{(8b - 16b(q_1 + q_2) + 12)} \\ &+ \frac{(8(1 + b - 2bq_1 - bq_2)c_1 + (1 - 2bq_2)(4c_2 + 2bt + 3t - 4bt(q_1 + q_2)))16b}{(8b - 16b(q_1 + q_2) + 12)^2} \end{aligned}$$

It is (strictly) positive if and only if

$$\begin{aligned} &8(1 + b - 2bq_1 - bq_2)c_1 + (1 - 2bq_2)(4c_2 + 2bt + 3t - 4bt(q_1 + q_2)) \\ &> (4c_1 + t(1 - 2bq_2))(2b - 4b(q_1 + q_2) + 3) \\ &\Leftrightarrow 2(1 - bq_2)c_1 + (1 - 2bq_2)c_2 > c_1(-4bq_2 + 3) \\ &\Leftrightarrow c_2 > c_1 \end{aligned}$$

The respective condition for $\frac{\partial k_2}{\partial q_2}$ is obtained by switching the subscripts.

The derivative $\frac{\partial k_1}{\partial q_2}$ is given by

$$\begin{aligned} \frac{\partial k_1}{\partial q_2} &= \frac{-8bc_1 - 2b(4c_2 + 2bt + 3t - 4bt(q_1 + q_2)) - 4bt(1 - 2bq_2)}{(8b - 16b(q_1 + q_2) + 12)} \\ &+ \frac{(8(1 + b - 2bq_1 - bq_2)c_1 + (1 - 2bq_2)(4c_2 + 2bt + 3t - 4bt(q_1 + q_2)))16b}{(8b - 16b(q_1 + q_2) + 12)^2} \end{aligned}$$

After a few transformations, one can show that this derivative is (strictly) negative if and only if

$$4(c_1 - c_2)(1 + 2b - 4bq_1) - (4b^2t + 12bt + 9t) + 8bt(q_1 + q_2)(2b + 3 - 2b(q_1 + q_2)) < 0$$

Define $\Psi := q_1 + q_2$. It is easy to show that the maximum of $8bt\Psi(2b + 3 - 2b\Psi)$ (over Ψ) is given by $4b^2t + 12bt + 9t$. Therefore, $-(4b^2t + 12bt + 9t) + 8bt\Psi(2b + 3 - 2b\Psi)$ is (weakly) negative. As $1 + 2b - 4bq_1$ is strictly positive, $\frac{\partial k_1}{\partial q_2}$ is negative unless $c_1 - c_2$ gets too large. Analogously, one can show that $\frac{\partial k_2}{\partial q_1}$ is negative unless $c_2 - c_1$ gets too large. This completes the proof of Lemma 1. ■

As Lemma 1 states, the price reactions to changes in q_1 and q_2 crucially depend on whether or not a firm has a cost advantage. If a firm indeed produces at lower costs, its hardware price increases, if its one copy protection is reduced, but decreases, if the other firm chooses lower copy protection. If, on the other hand, a firm has a cost disadvantage, price reactions may well be the other way round. Put differently, the firm producing at lower costs acts more aggressive than its competitor in that it punishes a decrease in copy protection of the opponent firm more strongly in terms of a hardware price reduction.

The choice of copy protection affects market shares directly (as seen for fixed hardware prices) and indirectly since the hardware prices are adjusted, if copy protection is changed. To see, whether the direct or the indirect effects are more important, we calculate market shares with endogenized prices. These are given by

$$b + 2a = 0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4bt(q_1 + q_2)} \quad (9)$$

for firm 1 and

$$1 - b - 2a = 0.5 + \frac{2(c_1 - c_2)}{3t + 2bt - 4bt(q_1 + q_2)} \quad (10)$$

for firm 2. It is easy to see that the firm producing at lower costs has a higher market share. Moreover, its market share decreases in the level of copy protection in either market, while the reverse is true for the firm producing at higher costs. Thus, the direct as well as the indirect effect is in some cases dominant. The firm producing at lower costs still benefits from reducing copy protection, as, in this way, it can increase its share in the market. As a direct consequence, the firm producing at higher costs still suffers from a reduction in its competitor's copy protection. Note that this is in line with the argumentation in the Playstation example stating that

the relatively low protection of Playstation's software helped Sony to take the place of Nintendo as leader in the video games market. Conversely to the situation with fixed prices, however, the low-cost firm's market share increases and, accordingly, the high-cost firm's market share gets smaller, if the latter firm chooses a lower copy-protection level. This is due to the aggressive strategy of the low-cost firm. If its competitor lowers the copy protection level, the firm reacts by sharply cutting hardware prices, which dominates the direct effect and overall leads to an increase in market share.

It remains to be shown, whether or not it is indeed beneficial for the firms to strategically reduce copy protection levels. To address this issue, we assume from now on that firm 1 is the low-cost firm, i.e. $c_1 < c_2$. Note that this is without loss of generality. Let us first determine the optimal copy probability q_2 . This is a very easy task. An increase in q_2 affects firm 2's profit in three ways: It leads to lower sales in the software market, as more people start copying software. Further, it yields a decrease in the hardware price k_2 as well as in firm 2's market share. As all these effects are negative, firm 2 does never gain from enabling product piracy and chooses the highest possible copy protection level. The following Lemma summarizes this result (proof in the text):

Lemma 2 *Firm 2 always sets $q_2 = 0$.*

To analyze, whether firm 1 is interested in enabling software piracy, we have to determine its profit (with endogenized hardware prices and the condition $q_2 = 0$). This profit is given by

$$\begin{aligned} \pi_1 = & \frac{(4(c_2 - c_1) + 2bt + 3t - 4btq_1)}{8b - 16bq_1 + 12} \left(0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4btq_1} \right) \quad (11) \\ & + \frac{(1 - q_1)bt}{2} \left(0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4btq_1} \right)^2 \end{aligned}$$

Making use of the profit formula, one can derive the following proposition, which contains the main result of the paper.

Proposition 1 *There exists a cut-off $\Delta\hat{c}$ for $c_2 - c_1$ such that the following holds. (i) For $c_2 - c_1 \leq \Delta\hat{c}$, firm 1 chooses q_i at its lowest possible value, i.e. $q_1 = 0$. (ii) For $c_2 - c_1 > \Delta\hat{c}$, firm 1 chooses $q_1 > 0$.*

Proof. We prove this Proposition by calculating the derivative $\frac{\partial\pi_1}{\partial q_1}$, which is (for $q_2 = 0$) given by

$$\begin{aligned} \frac{\partial\pi_1}{\partial q_1} = & \left(\frac{-bt}{2b - 4bq_1 + 3} + \frac{b(4(c_2 - c_1) + 2bt + 3t - 4btq_1)}{(2b - 4bq_1 + 3)^2} \right) \\ & \left(0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4btq_1} \right) + \frac{(4(c_2 - c_1) + 2bt + 3t - 4btq_1)}{8b - 16bq_1 + 12} \\ & \frac{8bt(c_2 - c_1)}{(3t + 2bt - 4btq_1)^2} - \frac{bt}{2} \left(0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4btq_1} \right)^2 \\ & + (1 - q_1) bt \left(0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4btq_1} \right) \frac{8bt(c_2 - c_1)}{(3t + 2bt - 4btq_1)^2} \end{aligned}$$

The derivative can be simplified to

$$\begin{aligned} \frac{\partial\pi_1}{\partial q_1} = & \frac{0.5t(2b + 3 - 4bq_1) + 2(c_2 - c_1)}{4t(2b + 3 - 4bq_1)^3} \\ & (4(c_2 - c_1)(5b + 6b^2 - 4b^2q_1) - bt(2b + 3 - 4bq_1)^2) \end{aligned}$$

From the last condition, it can easily be seen that $\frac{\partial\pi_1}{\partial q_1}$ is non-positive for each q_1 , if $c_2 - c_1$ is relatively low. In this case, firm 1 definitely chooses $q_1 = 0$. If, however, $c_2 - c_1$ becomes larger, there comes a point, where $\frac{\partial\pi_1}{\partial q_1}(q_1 = 0) > 0$, in which case firm 1 chooses $q_1 > 0$.

To complete the proof of Proposition 1, we have to show that the lower bound on $c_2 - c_1$ that is needed to make a reduction in copy protection worthwhile, is lower than the upper bound on $c_2 - c_1$ that is needed to ensure each firm a positive market share. The lower bound is given by the

condition¹⁶

$$4(c_2 - c_1)(5b + 6b^2 - 4b^2q_1) > bt(2b + 3 - 4bq_1)^2$$

$$\Leftrightarrow (c_2 - c_1) > \frac{t(2b + 3 - 4bq_1)^2}{4(5 + 6b - 4bq_1)} =: \Delta\tilde{c}$$

The upper bound results from the condition

$$0.5 + \frac{2(c_2 - c_1)}{3t + 2bt - 4btq_1} < 1$$

$$\Leftrightarrow (c_2 - c_1) < \frac{3t + 2bt - 4btq_1}{4} =: \Delta\bar{c}$$

It is then straightforward to show that

$$\Delta\bar{c} > \Delta\tilde{c} \Leftrightarrow 2 + 4b > 0$$

which is always fulfilled. Q.E.D. ■

We see that the low-cost firm may well be interested in enabling software piracy. This is due to two benefits: First, software piracy helps the firm to increase its market share.¹⁷ This leads to higher profit from both, hardware and software sale. Second, it affects market competition such that the firm charges a higher price for its hardware. These two benefits are increasing in the size of the cost heterogeneity. Hence, only if this heterogeneity is large enough, do the benefits of lowering copy protection outweigh the corresponding costs, which result from a higher fraction of copying consumers in the software market.

¹⁶The cut-off value in the following condition is denoted by $\Delta\tilde{c}$, while the corresponding cut-off value in Proposition 1 is denoted by $\Delta\hat{c}$. This different denotation is used, as $\Delta\hat{c}$ may depend on the specific value of q_1 . The current part of the proof, however, does hold for all values of q_1 .

¹⁷Note that this fits again very well to the Playstation example from the introduction.

5 Conclusion

In this paper, it was analyzed, whether firms in the video games market are interested in strategically enabling software piracy. It was shown that this is indeed the case, if firms differ substantially in hardware production costs. Then, the low-cost producer gains from enabling software piracy in two ways. First, it increases its market share in the hardware and, accordingly, in the software market. Second, it can raise its hardware price. These two benefits overcompensate the loss resulting from a higher fraction of pirating consumers in the software market.

We conclude by commenting on a further disadvantage of software piracy that was neglected in the model. It may be the case that consumers will be more willing to purchase a certain video games console, if many games for this console are available. Then, hardware producers might additionally be in competition for services of software producing firms. If a hardware producer reduces its copy protection level, while the other does not, software firms may decide to solely produce for the latter (especially, when producing for a second firm entails high costs) and this may hurt the first hardware producing firm. Note, however, that software piracy does not necessarily lower profits of software producing firms. As, in the model, the size of the low-cost firm's software market increases, if the firm lowers its copy protection, there is a positive effect on profits from software sale, too. If this positive effect is dominant, lowering copy protection levels is not problematic for the attraction of software producing firms.

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