Piracy in a two-sided software market*

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Abstract

This paper studies the impact of software piracy in a two-sided market setting. Software platforms attract developers and users to maximize their profits. The equilibrium price structure is affected by piracy. License fees to developers are lower with more piracy whereas the impact on user prices is ambiguous. A conflict over software protection may arise. Whereas developers gain by piracy, incompatible platforms may be hurt. Under compatibility incentives are aligned and both platforms and developers favor strict software protection.

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1 Introduction

Many software products are centered around platforms where a software platform has to attract software developers and users. One example is the market for game consoles where the console producer (such as Microsoft's Xbox 360, Nintendo's Wii, or Sony's PlayStation) has to attract gamers and game developers. Gamers only find the console attractive if a large amount of games are available. On the other hand, game developers only have an incentive to produce games if a large number of gamers can be reached. In this aspect, the market is characterized by two-sided externalities between gamers and game developers. The platforms' task is to charge prices so as to get both sides on board. Further examples that fit this description are the markets for operating systems (such as Microsoft's Windows) or e-book readers (such as Amazon's Kindle) where readers and publishers need to be attracted.

Piracy is a big issue in these markets. For example, in the market for video game consoles, it seems to be the platform sellers (Microsoft, Nintendo, Sony) who call for action against illegal sales of video games. In particular, they try to push for the prohibition of all kinds of copying modules or software.[1] At the same time, however, the availability of legal as well as illegal video games makes the video game console more attractive for gamers and hence potentially increases the platforms' profits. This ambiguity faced by video game consoles (and platforms in general) is best illustrated by a statement by David Reeves, President and CEO of Sony Computer Entertainment Europe (SCEE): "There is a piracy problem on PSP. (...) It sometimes fuels the growth of hardware sales, but on balance we are not happy about it."[2]

Another prominent example is the market for mobile-phone (smartphone) application software (or apps) running on a specific operating system.[3] A

[1]See, e.g., www.computerbild.de/artikel/cbs-News-DS-Nintendo-R4-Kopiermodul-Verbot-5499649.html and spiele.t-online.de/sony-geht-gegen-raubkopie-technik-fuer-ps3-vor/id_42692604/index. Note that this may also be due to the fact that such platforms of video game consoles often develop their own games which means that they are hurt by piracy just like independent developers.

[2]See www.mcvuk.com/news/30912/There-is-a-piracy-problem-on-PSP.

[3]Note that typically—and different from the market for game consoles—, operating system providers not only charge developers license fees market for smartphone ap-

study by 24/7 Wall St. reports that Apple (with their operating system Apple iOS) and their application developers for the iPhone and iPod Touch have lost more than $450 million as a result of illegal downloads. The study comes to the conclusion that for every paid download, there are three illegal downloads on average. For some applications, illegal download rates are as high as 95%.[4] Moreover, Apple claims that software like Cydia which helps unlock (or "jailbreak") its products "encourages the piracy of approved iPhone applications and is an expensive burden"[5] due to software problems resulting from jailbreaking. Apple's competitor Google offering an alternative operating system for smartphones (Android) and their developers also face lower profits due to downloads which were not legally purchased through Google's online application store, Android Market.[6]

This paper studies the issue of piracy and software protection in such a software market. We ask how platforms react to the threat of software piracy. Do they change the price structure? Do software firms necessarily lose from increased opportunities to pirate software? To this aim, we set up a two-sided market model for the software business. There are two platforms (game-console producers, e-book platforms, operating systems operators) that try to attract users to buy access to their platform and software developers that offer software suited for their platform. Software developers may decide whether to manufacture software for a platform; they may multi-home and offer their products on both platforms. Single-homing users choose between the two competing platforms and also decide whether to pirate software or purchase it legally.

plications but also royalties (or transaction fees) per (paid) download. Our model is restricted to license fees. This seems to be justified as a first step in light of the real-life market characteristics: whereas license fees differ, royalties are indeed the same across platforms, i.e., platforms compete in license fees (support) and (indirectly) through the number of potential users. More specifically, developers keep 70% and pay a share of 30% to the platforms (see http://www.apple.com/pr/library/2008/03/06iphone.html [App Store], http://www.android.com/us/developer-distribution-agreement.html [Android Market]) but fixed developer fees range from a one-time registration fee of $25 for Google's (open-source) Android (see http://market.android.com/support/bin/answer.py?hl=en&answer=113468) to $99/year for Apple's Standard Program or $299/year for the Enterprise Program (see http://www.apple.com/pr/library/2008/03/06iphone.html).

[4] See http://247wallst.com/2010/01/13/apple-app-store-has-lost-450-million-to-piracy/.

[5] http://www.nytimes.com/2009/05/13/technology/13jailbreak.html?_r=1&pagewanted=all.

[6] See http://www.businessinsider.com/android-piracy-2010-8#.

As is well known the price structure in two-sided markets depends heavily on the size of indirect network externalities between user groups (Armstrong, 2006; Rochet and Tirole, 2006). We show that piracy influences these indirect network effects. On the one hand, piracy leads to an immediate loss for software developers due to lower legal sales, thereby reducing the network externality from users on software developers. On the other hand, with more piracy, the expected surplus users get from the software market is higher as the market power of developers is reduced. This, in turn, increases users' valuations for having more software available at a platform. Thus, the network externality from firms on users is larger with more piracy. In consequence, with more piracy, platforms have to compete harder for developers.

Our main results are as follows: we show that incompatible software platforms react to more piracy by reducing license fees for developers. This is exactly because users are now more attracted by more software. This effect tends to increase software developers' profits and decrease platforms' profits. The impact on user prices is less clear. Platforms may increase or decrease the price depending on whether the opportunity cost of attracting an additional user increases or decreases. Thus, piracy may soften or intensify competition for users. We show that the software platforms' and individual software developers' profits may be affected in opposite directions by piracy. Software developers' profits are increased by more piracy and in turn the equilibrium amount of software is high. To the contrary, platform profits are lower under certain circumstances. Losses from selling licenses may not be compensated by increased revenues from users. Hence, our model suggests that there is a potential conflict of interest between developers and platforms. Whereas platforms may prefer strict software protection, individual software developers favor a low level of software protection.

The previous results are derived under the assumption that platforms are incompatible. The results change drastically in the case of compatible platforms where software developed for one platform can also be used on the other platform. It turns out that in this case both platforms and developers are affected negatively by piracy, i.e., software protection is in both developers' and platforms' best interest. The reason is that with compatible platforms, competition for users is already softened and it is independent of the strength of network externalities between users and software firms. This indicates that platforms may choose compatibility as a tool to join forces with software developers to fight piracy.

Most papers on software piracy model the software market as characterized by peer-group network externalities: the utility of a user increases in the number of other users who adopt the same software (Conner and Rumelt, 1991; Shy and Thisse, 1999).[7] In contrast, we take an explicit two-sided market view where users care about the amount of software that is available on a platform. This enables us to study the impact of piracy separately on the platform and on developers which is not possible in models based on peer-group network externalities. This distinction seems to be important as we show that these two players may be affected differently by piracy.

We also contribute to previous research that analyzes conditions under which piracy may be beneficial to firms.[8] In previous contributions, it is shown that in the presence of network externalities developers may benefit from software piracy. For a monopoly setup, Conner and Rumelt (1991) and Takeyama (1994) show that piracy may increase software firms' profits as piracy increases the total number of program users.[9] This intuition also holds in oligopoly settings as demonstrated in Shy and Thisse (1999) and Peitz (2004). Our paper differs from these contributions by taking a specific two-sided market view and by focusing on platform behavior.

Another mechanism why software firms may benefit from piracy is that it enables users to sample products. If free samples increase users' willingness to pay for legal copies, profits may increase (Peitz and Waelbroeck, 2006b). Complementarity between products may also lead to positive effects for firms. For instance, in the context of the music industry where music sales and concert attendance (or merchandize articles) can be thought of as complements, piracy of records may lead to increased demand for the

[7] Kiema (2008) takes a different route by assuming that counterfeiters who compete with the copyright owner incur advertising costs due to increased risk of punishment or digital-rights management (DRM) systems.

[8] A survey on piracy of digital products is provided by Peitz and Waelbroeck (2006a) and Belleflamme and Peitz (2010).

[9] Relatedly, Slive and Bernhardt (1998) demonstrate that in the presence of network externalities, non-protection of software can also be used as an instrument of price discrimination if groups differ in their willingness to pay and in the cost of being punished when using pirated products.

complementary product. Gayer and Shy (2006) show that this may lead to higher profits for artists who benefit from more concert attendance whereas record companies may suffer from lower record sales.

The rest of the paper is organized as follows. Section 2 describes the model setup. Section 3 presents the analysis of the base model. Section 4 discusses several extension to the base model. Finally, Section 5 concludes.

2 The model

This section introduces a model of piracy in a two-sided framework comparable to Choi (2007).

2.1 Software platforms

There are two horizontally differentiated software platforms. They are located at opposite ends of a Hotelling (1929) line. Platform 1 is located at 0 on the line of unitary length; platform 2 is located at 1. Platforms incur no marginal costs and fixed costs for setting up and running the business are normalized to 0. Platforms generate income from both users (by charging an access fee of p_i) and software developers (by charging a license fee l_i). In principle, both prices can be negative.[10]

2.2 Software users

Users are heterogeneous with respect to their preferences for the two platforms. We model users by being uniformly distributed along the unit interval. The location of a user is denoted by x. Users with a low value of x tend to prefer platform 1 while users with a high value of x tend to prefer platform 2. The utility of a user who is located at x and buys access to platform 1 is given by

$$u_1 = v + \theta n_1 - p_1 - \tau x. \tag{1}$$

[10]Note, however, that in equilibrium at most one side can be subsidized.

If this user chooses platform 2 instead, he derives a utility of

$$u_2 = v + \theta n_2 - p_2 - \tau(1 - x). \tag{2}$$

Users derive an intrinsic utility of v from buying access to a platform.[11] Moreover, users derive utility from software. The more software (n_i) is available for this platform the larger the utility. The benefit from an extra unit of software is given by θ. In Section 2.4 we will endogenize this parameter by modeling the interaction between software firms and users in detail. Users incur transportation costs of τ per unit of distance traveled. We assume that the market is covered which can be guaranteed by assuming that v is sufficiently large.[12]

The marginal user that is indifferent between joining platform 1 and 2 is given by

$$x_m = \frac{1}{2} + \frac{p_2 - p_1}{2\tau} + \frac{\theta(n_1 - n_2)}{2\tau}. \tag{3}$$

The market share of platform 1 is x_m whereas the market share of platform 2 is $1 - x_m$.

2.3 Software developers

A unit mass of software developers decides whether to manufacture software. Software developers may multi-home and offer products on both platforms. Developing software is associated with an investment of f. Software developers differ in these investment costs which we assume to be uniformly distributed on the unit interval.

Developers earn an expected amount of ϕ for each user they reach when offering their software on a platform. For now, we take this parameter as given but will provide a foundation in Section 2.4. In particular, we will show how this parameter is affected by software piracy.

Thus, the profit of a software developer producing for platform i is equal to

$$\pi^d = \phi s_i - l_i - f, \tag{4}$$

[11] This stand-alone value may be due to pre-existing software.
[12] This assumption will be relaxed later (see Section 4.2).

where s_i denotes the number of users at platform i and l_i denotes the license fee charged by platform i. Developers offer their product for platform i as long as they do not incur a loss, i.e., $\pi^d \geq 0 \Leftrightarrow f < \phi s_i - l_i = f_d$. All developers with $f < f_d$ enter. Under our assumption of the uniform distribution of development costs, the amount of software offered for platform i is given by

$$n_i = \phi s_i - l_i, \tag{5}$$

where $s_1 = x_m$ and $s_2 = 1 - x_m$.

2.4 Modeling the piracy decision

We now turn to the relationship between software firms and users in more detail. In particular, we focus on how this interaction is affected by piracy. We make use of a framework where legal and illegal software are vertically differentiated (Yoon, 2002; Belleflamme, 2003; Bae and Choi, 2006).

Suppose that each software developer is a monopolist and that each user buys one unit of software from each software firm. Users differ in their valuation δ for the software. This valuation is uniformly distributed on [0,1] (and independent of users' platform preferences). A user can opt between buying the software and copying it illegally. Illegal copies provide a lower utility than legally purchased software.[13]

The utility of a user δ for each software is

$$V = \begin{cases} \delta - p_s & \text{purchase a legal copy} \\ \beta\delta & \text{obtain an illegal copy,} \end{cases} \tag{6}$$

where $\beta \in (0, 1)$ measures the quality degradation of an illegal copy: the higher β the better a substitute the illegal copy and the larger the threat of piracy. The price charged by a software developer is p_s.

The user indifferent between buying and copying is given by $\bar{\delta} = p_s/(1-\beta)$ and hence legal demand is $1 - \bar{\delta}$. All users with $\delta \in (0, \bar{\delta})$ decide to obtain

[13] Reasons for a lower quality of an unauthorized copy could be, e.g., the lack of manuals or of technical support or the threat of being detected. See Yoon (2002) and Belleflamme (2003) for a more detailed discussion.

an illegal copy of the software. The price that maximizes profits under the threat of piracy is $p_s = (1-\beta)/2$.[14] This price is the lower the better is the quality of the illegal copy, that is, the larger is the threat of piracy. Each software monopolist earns profits of $(1-\beta)/4$. These profits are decreasing in β and hence a firm's monopoly power is constrained by piracy. These profits correspond to the network parameter ϕ. Hence, we set $\phi = (1-\beta)/4$. The surplus for users for each software product is $(1+3\beta)/8$ which corresponds to the network parameter governing the benefit users get from each additional software developer. Thus, we set $\theta = (1+3\beta)/8$.

Increased piracy opportunities—as measured by the quality of the illegal copy β— have two distinct effects. All else equal, more piracy reduces the benefits of the software developers (lower ϕ) and increases the benefits that go to the user (higher θ). Even though these two effects are derived from a simple model, we believe them to be of some robustness. It will turn out that both effects are important when it comes to competition between platforms. The strength of the effects will essentially determine the overall outcome. We will use this parameter β as our measure for the level of piracy where high values correspond to a high level of piracy.

2.5 Timing

The timing of the game is as follows: in the first stage, platforms simultaneously set prices for users and license fees for software developers. In the second stage, users and developers decide which platform(s) to join. In the third stage, users decide whether to buy software or copy it illegally. As is usual we solve the game by backward induction.

2.6 Assumptions

To guarantee the existence of a symmetric equilibrium, we need the following assumption:

Assumption 1. $8\tau > \theta^2 + \phi^2 + 6\theta\phi = \frac{17}{64} + \frac{11}{32}\beta - \frac{23}{64}\beta^2$.

[14] Note that in our setup it is always optimal for a software firm to accommodate piracy. Setting the limit price that deters all piracy is not profit-maximizing. For a discussion of this point, see Belleflamme (2003).

The assumptions states that network effects must not be too large compared to horizontal differentiation.

3 The analysis

This section analyzes the base model with incompatible platforms which means that software produced for one platform cannot be used by users of the rival platform. Hence, platforms' market shares on the user side depend on the amount of software available for this platform. Also, developers' incentives to offer software depends on the available number of users that can be reached. Thus, demands of users and developers are interrelated. Taking these interrelated demands into account, we solve equations (3) and (5) simultaneously to express demand in terms of prices only:

$$x_m = \frac{1}{2} + \frac{p_2 - p_1}{2[\tau - \theta\phi]} + \frac{\theta(l_2 - l_1)}{2[\tau - \theta\phi]}, \tag{7}$$

$$n_1 = \frac{\phi}{2} + \frac{\phi(p_2 - p_1)}{2[\tau - \theta\phi]} - l_1 + \frac{\theta\phi(l_2 - l_1)}{2[\tau - \theta\phi]}, \tag{8}$$

and

$$n_2 = \frac{\phi}{2} + \frac{\phi(p_1 - p_2)}{2[\tau - \theta\phi]} - l_2 + \frac{\theta\phi(l_1 - l_2)}{2[\tau - \theta\phi]}. \tag{9}$$

Expressions (7), (8) and (9) describe users' and developers' decisions to join a platform. Note that under Assumption 1 the denominator $\tau - \theta\phi$ is positive such that user demand at platform i decreases in the prices charged by this platform (p_i, l_i) but increases in the rival platform's prices (p_j, l_j). The same applies to developers' demand for a platform.

Platforms choose prices on both sides of the market as to maximize total profits:

$$\Pi_i = s_i p_i + n_i l_i, \tag{10}$$

where $s_1 = x_m$ and $s_2 = 1 - x_m$.

The first-order conditions for a symmetric equilibrium are

$$p^* = \tau - \phi(\theta + l^*) \tag{11}$$

and

$$l^* = \frac{\phi\tau - \theta p^* - \theta\phi^2}{4\tau - 3\theta\phi}. \tag{12}$$

It is instructive to interpret the first-order condition with respect to user prices (equation (11)) in detail. Without network effects, the equilibrium price for users coincides with the standard Hotelling price $p^* = \tau$. Taking the externalities between users and software developers into account, the price for users the price is corrected downwards by the term $\phi(\theta + l^*)$. This term measures the external benefit of attracting one additional user. The term $\theta + l^*$ is the benefit the platform gets from one extra developer through the license fee (l^*) and the extra revenue the platform can extract from users per extra developer (θ). The term ϕ gives the number of developers that enter if one extra user is attracted (see equation (5)). Thus, the external benefit or opportunity cost is given by the total term $\phi(\theta + l^*)$. Note that the strength of this opportunity cost is affected both by user surplus in the software market (θ) and by the profitability of software developers (ϕ). As piracy has opposite effects on these two parameters the overall effect of piracy on the opportunity costs of attracting users is a priori ambiguous.

Solving equations (11) and (12) yields the equilibrium price for users and the equilibrium license fee:

$$p^* = \tau - \frac{3}{4}\theta\phi - \frac{1}{4}\phi^2 \tag{13}$$

and

$$l^* = \frac{1}{4}[\phi - \theta]. \tag{14}$$

The user price is lower than the standard Hotelling price due to the network effects. The stronger these network effects the lower is the price. The license fee charged to software firms increases with the profit per user (ϕ) that developers can generate, but decreases with the benefit users get from an additional unit of software (θ). The intuition for this is as follows. If users value additional software highly, platforms compete tough so as to attract a large number of software manufacturers which in turn attracts users. In turn, license fees are low.

The following proposition studies the impact of piracy on equilibrium prices:

Proposition 1. i) If $\beta \in (0, 1/7)$, user prices decrease with better piracy opportunities. If $\beta \in (1/7, 1)$ prices increase with better piracy opportunities. ii) The license fee charged to software developers decreases with more piracy.

Proof. By differentiating expressions (13) and (14) with respect to β. □

From expression (13) it can be seen that the user price decreases in both network externality parameters. However, as those are affected in opposite directions by more piracy, the overall effect is ambiguous. The intuition for this ambiguity has been explained when discussing the first-order condition (11). The overall opportunity costs of attracting additional users may rise or fall with more piracy. Whereas the reduced developers' profitability (ϕ) reduces the incentives to compete for users, users' increased surplus from software increases the incentives for platforms to compete tough for users. If users do not benefit to a large extent from piracy (low beta) and hence firms only suffer a minor loss in profits, then the network externality on the developer side plays a relatively greater role. As a result, attracting users becomes more important which results in lower prices for users. The opposite is true if developers are hit a lot harder by piracy. Thus, piracy may weaken or intensify competition for users. The impact of piracy on license fees, however, is unambiguous. Both effects point into the same direction. If users value additional software highly, platforms compete tougher for them so that license fees are reduced. This effect is reinforced by the fact that platforms compensate software developers for losses due to less legal sales.

Adding up revenues from license and user sales, the resulting equilibrium profit for each platform amounts to

$$\Pi^* = \frac{\tau}{2} - \frac{1}{16}\phi^2 - \frac{1}{16}\theta^2 - \frac{3}{8}\theta\phi. \tag{15}$$

The following proposition studies the impact of piracy on platform profitability:

Proposition 2. If $\beta \in (0, 11/23)$, platform profits decrease with more piracy. If $\beta \in (11/23, 1)$, platform profits increase with more piracy.

Proof. By differentiating expression (15) with respect to β. □

The proposition shows that platforms' preferences for piracy are ambiguous and depend on the extent of substitutability of legal and illegal software. There are two effects at work. We have seen above that a platform reacts to more piracy by charging lower license fees. However, competition for users may be relaxed if $\beta \in (1/7, 1)$. Only if this second effect is sufficiently strong, platforms may actually benefit from piracy.

The software developers'[15] joint profit is given by

$$(\pi^d)^* = \frac{1}{16}[\phi + \theta]^2 \tag{16}$$

and the equilibrium number of software firms on each platform is

$$n^* = \frac{1}{4}(\phi + \theta). \tag{17}$$

Whereas piracy may be positive or negative for software platforms, the effect on software developers is unambiguously positive:

Proposition 3. i) Total profits of software developers are higher with piracy. ii) The number of software applications increases with piracy.

Proof. By differentiating expressions (16) and (17) with respect to β. □

Developers' profits increase as platforms are more eager to attract them as users value more software to a large extent when piracy is high. In turn, license fees are low and compensate the immediate losses due to lower legal sales revenues. Note that developers' profits depend on $\theta + \phi$ which corresponds to the total surplus (user surplus plus profits) in each software market (see equation (16)). Whenever piracy increases the total surplus of the interaction between software firms and users, profits of individual software firms increase. Thus, software firms may actually benefit from reduced market power due to the two-sidedness of the market. As profits of individual software firms increase, this immediately leads to more entry by software

[15] Clearly, the marginal software developer makes zero profit.

firms with higher development costs and hence, software variety increases with more piracy.

Interestingly, the result here is different from the outcome in Gayer and Shy (2006). As pointed out in the introduction, in their paper, artists benefit from more piracy as it increases concert attendance but music companies lose out. Applying this logic to the present context, one would expect developers to pay the price for pirating activity here as well. This, however, is not the case as platforms also set prices on the developer side. By doing so, they indirectly profit from higher developer revenues and therefore are hit harder if piracy becomes an issue.

Our results so far point to a potential conflict of interest between developers and software platforms with respect to protection strategies. If $\beta \in (0, 11/23)$, developers prefer a low level of software protection while platforms are interested in tough protection. Only for $\beta \in (11/23, 1)$ incentives are aligned. This complements the existing literature. Most papers focus on the impact of piracy on individual software developers. They find that in the presence of network effects, individual software developers may benefit from relaxing software protection, both in monopoly (Conner and Rumelt, 1991; Takeyama, 1994; Slive and Bernhardt, 1998) as well as in oligopoly settings (Shy and Thisse, 1999; Peitz, 2004). In contrast, the focus in our paper is on software platforms acting as intermediaries between users and software developers. We show that piracy may lead to conflicting interests between platforms and individual software developers. Software developers benefit from piracy as the interaction between users and software firms leads to more surplus in cases where piracy is possible.

Next, we are interested in the welfare impact of piracy. User surplus (net of transportation costs and the intrinsic utility of connecting to a platform[16]) is given by

$$CS^* = \theta n^* - p^* = \frac{1}{4}(\theta^2 + \phi^2) + \theta\phi - \tau. \tag{18}$$

Adding up platform profits, developers profits and user surplus, total wel-

[16] Transportation costs and the intrinsic utility from access to a platform v are independent of the level of piracy, and hence, can be neglected.

fare in this market can be expressed as:

$$W^* = \frac{3}{16}(\phi + \theta)^2. \tag{19}$$

The following proposition characterizes the welfare properties:

Proposition 4. i) If $\beta \in (0, 7/11)$, user surplus increases with better piracy opportunities. If $\beta \in (7/11, 1)$, user surplus decreases with better piracy opportunities. ii) Total welfare increases with piracy.

Proof. By differentiating expressions (18) and (19) with respect to β. □

Piracy influences user surplus in three ways. Firstly, there is an immediate positive influence as software users receive a higher surplus from software consumption (θ increases in β). Secondly, the number of available software increases which is also positive for users. Thirdly, the users' price for platform access changes. According to Proposition 1 this last effect can be positive or negative. The overall effect on user surplus is ambiguous and this last effect may dominate. In particular, if the piracy level is already high, users may suffer from more piracy as prices for platform access rise disproportionately. Total welfare increases with piracy. As can be seen in equation (19) equilibrium welfare depends only on the total surplus in the software market ($\phi + \theta$) which rises with piracy. Note that for total welfare, access prices to the platform do not matter as these prices are mere transfers between users and platforms.

4 Extensions

This section discusses several extensions to our base model.

4.1 Piracy with compatible platforms

Suppose that in contrast to the base model, platforms are now compatible which means that platforms have agreed on a common standard such that software created by any developer can be used on both platforms. As a consequence, the amount of software is no longer a means of vertical differentiation and platforms' user market shares depend only on the price, but not on the amount of software available (which is necessarily the same on both platforms):

$$x_m = \frac{1}{2} + \frac{p_2 - p_1}{2\tau}. \tag{20}$$

In equilibrium, user prices then correspond to the ones in a standard Hotelling setup and are equal to $\bar{p} = \tau$.

Suppose that platforms offer the license to produce software jointly and then divide the revenues in equal shares. The total income from selling licenses is $(\phi - l)l$ which is maximized at

$$\bar{l} = \frac{\phi}{2}. \tag{21}$$

Note that with compatibility platforms never subsidize developers. The equilibrium license fee is strictly positive. Profits for each platform are then given by

$$\bar{\Pi} = \frac{\tau}{2} + \frac{\phi^2}{8}, \tag{22}$$

where the first term is the income from sales to users and the second term is the income from selling licenses to software developers. As the impact of piracy on ϕ is negative, more piracy leads to a downward correction of demand for software and in consequence to lower license fees and lower income. With compatible platform there is no positive effect of competition for users which could compensate for these losses. Hence, platform profits decrease with piracy. In turn, software developers' profit are also reduced when piracy increases and the amount of software is lower when piracy is high.

Proposition 5. If platforms are compatible, both platform profits and software developers' joint profit are lower with more piracy.

This extension shows that the effects of piracy depend on the way software platforms are organized. This can be important if overall software protection depends on the efforts of both platforms as well as developers. In these cases, choosing compatibility can serve as a means to align incentives in order to fight software piracy more effectively.

4.2 Piracy in growing markets

Suppose that the market for user access to platforms is not fully covered and each platform can act as a monopolist. This setup can be used to study the impact of piracy in a growing market where firms do not compete against each other, but rather to expand the market.

From equation (1) demand at each platform is equal to

$$x_i = \frac{v + \theta n_i - p_i}{\tau} \tag{23}$$

and the number of developers that enter the market is

$$n_i = \phi x_i - l_i. \tag{24}$$

The demand functions for users and developers are still interrelated such that more users enter the market if more software is available and vice versa. Solving the demand functions and maximization of profits leads to following equilibrium prices:

$$p^* = \frac{v(2\tau - \phi^2 - \theta\phi)}{4\tau - (\theta + \phi)^2} \tag{25}$$

and

$$l^* = \frac{v(\phi - \theta)}{4\tau - (\theta + \phi)^2}. \tag{26}$$

The equilibrium profits of platforms and of each developer (net of development costs) then amount to

$$\Pi^* = \frac{v^2}{4\tau - (\theta + \phi)^2} = \frac{v^2}{4\tau - \left(\frac{3+\beta}{8}\right)^2} \tag{27}$$

and

$$\Pi_d^* = \frac{v(\theta + \phi)}{4\tau - (\theta + \phi)^2} = \frac{v(\frac{3+\beta}{8})}{4\tau - \left(\frac{3+\beta}{8}\right)^2}. \tag{28}$$

Differentiation of equilibrium profits with respect to β leads to the following result:

Proposition 6. If the user market is not covered, both platforms and software developers benefit from more piracy.

The proposition highlights the fact that the impact of piracy depends on whether a market is growing or saturated. In a growing market, piracy may help to expand the number of users willing to buy access to a platform as the expected surplus from users' interaction with software is larger (higher θ). This expansion of the market is beneficial for platforms such that platform profits increase. This effect is not present in a saturated market where platforms compete against each other. The impact on software developers is the same in growing and in saturated markets; they unambiguously benefit from more piracy. A similar point has been made Minniti and Vergari (2010), albeit in a market without network effects concluding that firms are less likely to oppose piracy in growing markets.

5 Conclusion

This paper analyzes the impact of piracy in the software industry. The setting we use is that of a two-sided market perspective. Users of software platforms are interested in a large amount of software. Software developers are interested in offering software for platforms with many users. It is the task of the platform to set prices to users and developers taking the externalities between these two groups into account. Software piracy influences these cross-group externalities. On the one hand, piracy negatively affects immediate legal sales from software developers. On the other hand, piracy increases the surplus users get from each additional unit of software that is developed.

Our results point to a conflict over software protection strategies between software platforms and software developers. Whereas software developers benefit from piracy, the impact on incompatible software platforms is ambiguous and platforms may suffer or benefit from piracy. We point out that by choosing compatibility, platforms may align incentives of all players. In this case, developers and platforms are both interested in reducing piracy. We also demonstrate that in growing markets, platforms and software developers may be in favor of piracy. In contrast to saturated markets, the number of customers adopting the market can be increased through piracy.

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