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The Impact of Piracy on Prominent and Non-prominent Software Developers*

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Abstract

This paper studies the impact of software piracy on prominent and non-prominent software developers in markets based on a two-sided platform business. Consumer behavior is imperfect and, when adopting a platform, consumers only take prominent software into account. We show that prominent software exhibits higher piracy rates than non-prominent software. However, contrary to intuition, this does not necessarily mean that prominent software developers benefit more from increased software protection. Indeed, we show that prominent developers may lose out whereas non-prominent developers may gain from better software protection.

Keywords: Piracy; Platform; Software; Two-sided market.
JEL-Classification: L11; L86.

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1 Introduction

Many software products are centered around platforms. Examples for these industries include game consoles, e-book readers, and applications for smartphones. In particular, applications for smartphones or tablet PCs have gained much importance in recent years. Common to all these examples is that the platform has to attract two sides. Consider the examples of game consoles. There, a platform (i.e., the game console such as Microsoft's Xbox 360, Nintendo's Wii, or Sony's PlayStation) has to attract gamers (users who buy the game console) and game developers. Users only find the game console attractive if many games are available; at the same time, game developers only find the platform attractive if they can reach many gamers. In this aspect, these markets are characterized by two-sided network externalities (see, e.g., Armstrong, 2006; Caillaud and Jullien, 2003; Hagiu, 2006, 2009; Rochet and Tirole, 2003, 2006).

Piracy of software seems to be a growing concern in these markets, potentially leading to losses for both developers and platforms.[1] Our study is in particular motivated by the steadily growing market for software applications (so-called apps) which are popular among users of Internet-compatible digital devices such as smartphones or tablets. In this market, operating systems (such as Android [Google], BlackBerry OS [BlackBerry], iOS [Apple], Windows Phone [Microsoft]) act as platforms and software developers provide applications which run on the operating systems. As a matter of fact, many sources point out that overall software piracy seems to be a major issue in this market with some apps and/or games having piracy rates of more than 90%.[2] However, software developers seem to be affected differently by illegal downloads and software piracy. A recent study by the Yankee Group and Skyhook investigating the impact of app piracy on 75 Android developers revealed that 27% consider piracy a "huge problem" and another 26% consider it "somewhat of a problem".[3] This means that slightly less than half of the developers surveyed appear not very concerned by the existence of piracy. In a survey of UK videogame developers, the trade in-

[1] See Rasch and Wenzel (2013) for examples and sources.

[2] See, e.g., `http://www.guardian.co.uk/technology/appsblog/2012/jul/23/dead-trigger-android-free-piracy`.

[3] See `http://www.yankeegroup.com/about_us/press_releases/2011-09-08-1.html`.

dustry group TIGA found that only 10% of developers considered piracy a threat to their business survival but 90% viewed it a "constant or increasing problem". However, 30% would not do business differently as a direct consequence from the existence of piracy (with 50% saying they were in favor of a change in business practices and 20% answering "don't know").[4] This raises the question why firms have such different views on piracy. In this paper, we will provide a possible explanation, based on different prominence levels, why some software firms within an industry may favor piracy (or are affected to a lesser extent) whereas others may not.

We study the impact of piracy when software developers are differentiated according to prominence. Prominent and non-prominent software differs in two dimensions. Firstly, under a prominent piece of software we understand a piece of software that is known by users well in advance of adopting a platform and which is important for their adoption decision. Other pieces of software are less well known and do not play a role in a user's adoption decision. Secondly, given that prominent software is better known, it is reasonable that prominent software is more likely to be purchased by a user than a non-prominent piece of software. We model this by assuming that users derive a higher utility from prominent software.

The important assumption imposed in this model is that users are fully informed about the availability of prominent software before adopting a platform whereas users discover some other, non-prominent software only after they have adopted a software platform. Hence, at the adoption stage, only prominent software is considered which means that the availability of a prominent piece of software may have a large impact on market shares on the user side.[5] To the contrary, whether a non-prominent piece of software is available or not does not influence users' adoption decisions. However, we think that this myopic user behavior is reasonable in many instances.

Let us discuss this main assumption and the motivation for using it in more detail. Consider, for example, a situation where a user wants to buy a new smartphone. Given the extremely large number of applications available on the different operating systems, it is almost impossible for a customer

[4]See `http://www.gamepolitics.com/2009/11/11/uk-dev-survey-piracy-problem-not-threat#.USTcuq5STxo`.

[5]In this aspect, our notion of prominence is closely related to 'must-have' components in Hogendorn and Yuen (2009).

to know all of them. Most likely, the customer will be only aware of major applications (prominent software) but not of other, less prominent software. Thus, at the adoption stage, only the prominent software matters.[6] Over time and after having gained some experience on the software platform, the customer may discover software he was initially unaware of and which he then eventually decides to purchase.

Within our framework we provide two main results. Firstly, given its larger popularity, prominent software is more likely to be pirated by users. That is, prominent software exhibits a higher piracy rate than non-prominent software. However, contrary to basic intuition, this does not necessarily mean that prominent developers benefit more from additional software protection, which is our second main results. Indeed, we show that piracy and software protection may affect software developers quite differently depending on whether a developer is prominent or not. The reason lies in the platforms' pricing strategies toward these different types. Platforms have an incentive to subsidize prominent developers to attract more users. This effect is not present (or only to a smaller extent) with non-prominent developers. Thus, software protection has two effects for developers. Firstly, it increases developers' immediate revenues from software sales to users. This positive effect of software protection applies to both types of developers. Secondly, with stricter software protection, users value additional software less (as software prices tend to be higher with more protection) inducing platforms to compete less hard for developers. In other words, piracy induces platforms to compete harder for developers. This leads to reduced license fees for prominent developers. This second, negative effect of software protec-

[6]Note that one may argue that the most established applications are usually available on the most popular operating systems Android and iOS and that, as a consequence, differences in software may not matter that much for a consumer deciding between those two platforms. However, this is not necessarily the case for other platforms with a lower user base, such as BlackBerry OS or Windows Phone. Indeed, it has been pointed out that the lack of a sufficiently large number of available applications has contributed to the low (declining) market shares of those platforms. In that sense, the existence of established software on a mobile platform appears an important aspect for users' adoption decisions (see, e.g., `http://www.crn.com/news/mobility/232301056/the-decline-of-blackberry-where-rim-went-wrong.htm` or `http://www.cnet.com/news/blackberrys-loss-is-windows--phones-gain/`). A comparison of the (non-)availability of the top 50 free and top 50 paid apps featured in the Apple App Store and Google Play in the United Stated on BlackBerry World and Windows Phone store yielded a rate of only 34% as of May 21, 2013 (see `http://www.canalys.com/newsroom/top-ios-and-android-apps-largely-absent-windows-phone-and-blackberry-10`).

tion applies only to prominent developers. As a result, due to the first effect, stricter software protection is positive for non-prominent firms. For prominent developers, the second effect may outweigh the first one making them possibly benefit from less software protection.

By now there is a growing literature on firm competition in the presence of myopic user behavior.[7] Related to our paper, models have been developed where consumer take only a subset of price components into account when selecting a product (Gabaix and Laibson, 2006; Spiegler, 2006).[8] This literature is also concerned with the effects of a firm's prominence by either assuming that a prominent firm serves as the default option (Piccione and Spiegler, 2009; Gu and Wenzel, 2013) or, in the context of search, by assuming that a firm's prominence affects a consumer's search order (Armstrong et al., 2009; Armstrong and Zhou, 2011). We build on this literature by providing a model where consumers are myopic regarding their platform adoption decision and take only prominent software into account when choosing which platform to adopt. The main focus of this paper is how this imperfect, myopic consumer behavior affects platform pricing and the effects of piracy on prominent and non-prominent software developers.

The literature on piracy in platform markets is very limited.[9] With the exception of Rasch and Wenzel (2013) who focus on the (mis)alignment of platforms' and developers' software protection incentives, we are not aware of further studies concerning this issue. However, given the increased importance of software markets, which are organized as two-sided markets, software piracy in these markets is getting more important. In contrast to Rasch and Wenzel (2013), in this paper we consider imperfect consumer behavior and explore how heterogeneous software developers, which differ in their prominence, are affected by software piracy. We show that it is important to take this myopic consumer behavior into account since the different types of software developers may be affected differently by piracy.

The remainder of the paper is organized as follows. In Section 2, we describe the model setup. Section 3 presents our main results. Section 4 discusses two extensions of the base model. Finally, Section 5 concludes.

[7] A survey is provided by Huck and Zhou (2011) and a textbook by Spiegler (2011).
[8] See also Armstrong and Vickers (2012) for an application to financial products.
[9] For a survey on digital piracy, see Belleflamme and Peitz (2012).

2 The model

This section introduces a model of piracy in a platform framework. The model draws on the two-sided-market models of Armstrong (2006), Choi (2010), and Belleflamme and Peitz (2010) as well as on the piracy model by Rasch and Wenzel (2013).

Software platforms

There are two software platforms located at opposite ends of a unit line where platform 1 is located at 0 and platform 2 is located at 1 (Hotelling, 1929). Platforms generate income from both users (by charging an access fee of p_i, $i \in \{1, 2\}$), prominent software developers (by a charging license fee l_i), and non-prominent software developers (by a charging license fee $\hat{l}_i$). All possible costs are normalized to zero.

Software developers

There is a unit mass of software developers which come in two types. A fraction γ are prominent developers and a fraction $1 - \gamma$ are non-prominent developers. Prominent and non-prominent developers differ in two aspects: (i) when adopting a platform, only prominent software is taken into account by users and (ii) prominent software offers a higher (base) utility to users than non-prominent software.

Software developers may multi-home and offer software products on both platforms. Developing software is associated with an investment of f which is uniformly distributed on the unit interval, independently for each type.

The profit of a prominent software developer that produces for platform i amounts to

$$\pi = \phi s_i - l_i - f,$$

where s_i denotes the number of users at platform i and ϕ is the amount a developer earns for each user reached on the platform. For now we take ϕ as

given but we will provide a foundation below.[10] In principle, the amount a developer earns depends on its pricing strategy as well as on the level of software protection. The license fee l_i and the investment cost f is subtracted from revenues.

Analogously, the profit of a non-prominent software developer that produces for platform i amounts to

$$\hat{\pi} = \hat{\phi} s_i - \hat{l}_i - f.$$

Note that profits per user may differ for prominent and non-prominent software. In addition, platforms may also set different license fees for prominent and non-prominent developers.

Developers offer their product on a platform i as long as they do not incur a loss, i.e., $\pi \geq 0 \Leftrightarrow f < \phi s_i - l_i =: \bar{f}$ and $\hat{\pi} \geq 0 \Leftrightarrow f < \hat{\phi} s_i - \hat{l}_i =: \hat{\bar{f}}$. All developers with $f < \bar{f}$ and $f < \hat{\bar{f}}$ enter.

Assuming that the platforms can price-discriminate between the two types of software, the amount of prominent and non-prominent software on platform i can then be expressed as

$$n_i = \gamma(\phi s_i - l_i) \tag{1}$$

and

$$\hat{n}_i = (1 - \gamma)(\hat{\phi} s_i - \hat{l}_i).$$

Software users

Users who only buy from one of the two platforms (i.e., they single-home) are distributed uniformly along the unit interval. The location of a user is denoted by x. When making the adoption decision, users are only aware of the amount of prominent software. Thus, at the decision stage, the perceived utility of a user who is located at x and who buys access to platform

[10] Note that, in principle, the amount a developer earns for each user may also depend on the adopted platform. However, as platforms are identical (apart from the available software), the value of a software product is identical across platforms and, hence, the earnings per consumer does not depend directly on the platform. A similar reasoning applies to the benefit a user receives from software consumption, which is introduced below.

1 or platform 2, respectively, is given by

$$u_1 = v + \theta n_1 - p_1 - \tau x$$

and

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

Users derive an intrinsic utility of v from buying access to a platform.[11] The more prominent software n_i is available on a platform the higher is a user's perceived utility. The benefit from an extra unit of prominent software is given by θ. Below we will endogenize this parameter by modeling the interaction between software firms and users in detail. Again, it will mainly depend on the developers' pricing strategy and on the extent of software protection. Users incur linear transportation costs of τ per unit of distance traveled.

Platforms' market shares in the user market depend on user prices and the amount of prominent software. The market share of platform i is determined by the user who is indifferent between buying from either of the two platforms and is given according to the Hotelling formula:[12]

$$s_i = \frac{1}{2} + \frac{\theta(n_i - n_j) - p_i + p_j}{2\tau}. \tag{2}$$

Piracy decision

We adopt a framework where legal and illegal software is vertically differentiated (Yoon, 2002; Belleflamme, 2003; Bae and Choi, 2006). Suppose that each software developer is a monopolist and that each user may buy one unit of software from each software firm. This specification implies that although users are not aware of non-prominent developers before the decision which platform to go to, they may buy their products later on. 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 choose between buying the software and copying it illegally. A user

[11] This stand-alone value may be due to pre-existing software or additional features the platform offers (e.g., the possibility to watch DVDs or Blu-rays on game consoles).

[12] We assume that the market is covered, i.e., any user along the linear city buys access to exactly one platform. This can be guaranteed by assuming v sufficiently large.

may also decide not to use the product. Illegal copies provide a lower utility than legally purchased software (e.g., due to a lack of manuals/technical support or blocked access to an online community).

The utility of a user δ considering to buy a prominent piece of software is

$$V = \begin{cases} \delta - p_s & \text{purchase a legal copy,} \\ (1-\alpha)\delta - k & \text{obtain an illegal copy,} \\ 0 & \text{otherwise,} \end{cases} \tag{3}$$

where $\alpha \in (0,1)$ measures the quality degradation of an illegal copy. There is a (fixed) cost k associated with pirating a software product. This fixed cost will be our measure of software protection. Better protected software is harder to pirate, and hence, the lower is the threat of piracy. The price charged by a prominent software developer is p_s.

Users derive a lower utility from consuming a non-prominent software product. This is captured by a parameter $\beta \in (0,1)$ that measures the discount on the base utility of a non-prominent piece of software relative to a prominent one:

$$\hat{V} = \begin{cases} \delta\beta - \hat{p}_s & \text{purchase a legal copy,} \\ (1-\alpha)\delta\beta - k & \text{obtain an illegal copy,} \\ 0 & \text{otherwise,} \end{cases}$$

where $\hat{p}_s$ is the price charged by a non-prominent developer.

We assume that the costs of obtaining an illegal copy must not be too high:

Assumption 1.

$$k \leqslant \frac{\alpha(1-\alpha)\beta}{1+\alpha} =: \bar{k}.$$

This assumption ensures that in equilibrium some users indeed obtain an illegal copy so that it is optimal for software developers to accommodate piracy.[13]

[13] Setting the limit price that deters all users from obtaining the software illegally is only profit-maximizing if the costs of piracy are higher than imposed under *Assumption 1*. For an analysis of this case, see Yoon (2002) and Belleflamme (2003).

Timing

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, software developers set the prices for their products and in the fourth stage, users decide whether to buy software or copy it illegally.

3 Results

User piracy and the pricing of software

We start the analysis by studying users' piracy decisions and the optimal price setting by software firms. At this stage, platform adoption decisions (by users and software developers) as well as platform prices are given.

We start with the consumption decision of a user regarding a prominent piece of software. According to the utility function (equation (3)), the user who is indifferent between buying the legal product and obtaining an illegal copy is given by $\bar{\delta} := (p_s - k)/\alpha$. The marginal user who is indifferent between obtaining the pirated copy and not consuming is $\underline{\delta} := k/(1-\alpha)$. Hence, all users with $\delta \geqslant \bar{\delta}$ purchase the product and all users with $\bar{\delta} > \delta \geqslant \underline{\delta}$ copy it illegally. Users with valuation lower than $\underline{\delta}$ do not consume the software.

For a given software price p_s, the prominent software developer expects to earn an income of $p_s(1 - (p_s - k)/\alpha)$ from selling the software to a user. The optimal price is set at $p_s = (\alpha + k)/2$. Thus, from the interaction with each user, a prominent software firm expects a revenue of $\phi(k) = (\alpha + k)^2/4\alpha$.[14] Note that ϕ strictly increases with the level of software protection. This implies that, for given adoption decisions by users and developers, a prominent firm benefits from stricter software protection.

Denote by $\bar{\delta}^*$ the marginal user who is indifferent between copying and purchasing a legal copy given the optimal price. The expected surplus of a user

[14] We will write ϕ instead of $\phi(k)$ for simplification purposes in the following.

for each prominent software product can be expressed as

$$\theta = \int_{\underline{\delta}^*}^{\bar{\delta}^*} ((1-\alpha)\delta - k)d\delta + \int_{\bar{\delta}^*}^{1} \left(\delta - \frac{\alpha + k}{2}\right) d\delta.$$

Simplification yields $\theta(k) = (4-3\alpha)/8 - 3k/4 + (1+3\alpha)k^2/8\alpha(1-\alpha)$.[15] Note that θ decreases in the level of software protection k. Finally, we can also derive the piracy rate of a prominent software product given the optimal prices. This piracy rate amounts to $\bar{\delta}^* - \underline{\delta}^* = 1/2 - k(1+\alpha)/2\alpha(1-\alpha)$.

In a similar way, we can derive the optimal price set by developers of non-prominent software. The only difference that arises is that the user utility from consuming this type of software is discounted by a factor β. We obtain the optimal price for non-prominent software as $\hat{p}_s = (\alpha\beta + k)/2$ and revenue per user of $\hat{\phi} = (\alpha\beta + k)^2/4\alpha\beta$. Non-prominent software exhibits a piracy rate of $\hat{\bar{\delta}}^* - \hat{\underline{\delta}}^* = 1/2 - k(1+\alpha)/2\alpha(1-\alpha)\beta$.

Our first result compares the piracy rates of prominent and non-prominent software:

Proposition 1. The piracy rate of prominent software is higher than of non-prominent software.

The proposition shows that prominent software developers suffer to a greater extent from piracy than non-prominent developers. The result also implies that, for given adoption decisions, prominent developers would benefit to a larger degree from increased software protection. However, in the following analysis we will show that these preferences towards software protection may be reversed, in particular for prominent software developers, if adoption decisions are taken into account.

Adoption decisions and platform behavior

We now analyze the adoption decisions and the price decisions by the platforms.

[15] In what follows, we will write θ instead of $\theta(k)$ for simplification.

The adoption decisions by users and prominent software developers are interrelated and, hence, the demand for users and prominent developers at a platform is interrelated. To take this into account, we solve equations (1) and (2) simultaneously and express demand in terms of prices only, i.e.,

$$s_i = \frac{1}{2} + \frac{\gamma\theta(l_j - l_i) - p_i + p_j}{2(\tau - \gamma\theta\phi)}$$

and

$$n_i = \gamma\left(\phi\left(\frac{1}{2} + \frac{\gamma\theta(l_j - l_i) - p_i + p_j}{2(\tau - \gamma\theta\phi)}\right) - l_i\right).$$

User demand is independent of the amount of non-prominent software available on a platform. However, the demand for non-prominent software developers depends on the market share on the user side:

$$\hat{n}_i = (1-\gamma)\left(\hat{\phi}s_i - \hat{l}_i\right).$$

Platform profits depend on three sources: access prices from users and license fees from both prominent as well as from non-prominent software developers. Hence, profits of a platform i are given by

$$\Pi_i = s_i p_i + n_i l_i + \hat{n}_i \hat{l}_i.$$

In the symmetric equilibrium, platforms charge the following prices:[16]

$$p^* = \tau - \frac{3\gamma\theta\phi + \gamma\phi^2 + (1-\gamma)\hat{\phi}^2}{4}, \tag{4}$$

$$l^* = -\frac{\theta - \phi}{4},$$

and

$$\hat{l}^* = \frac{\hat{\phi}}{4}.$$

Proposition 2. (i) Platforms may subsidize prominent developers, that is, the license fee for prominent developers may be negative. (ii) The optimal license fee for non-prominent developers is positive. (iii) User prices are

[16] We focus on market-sharing equilibria. This can be guaranteed by assuming that horizontal differentiation among the platforms is sufficiently large.

lower the more prominent software there is (higher γ).

Proof. Ad (i): follows as $\phi > 0$ and $\theta > 0$. The license fee is negative (positive) if $\theta > (<)\phi$. Ad (ii): follows from the fact that $\hat{\phi} > 0$. Ad (iii): by differentiating expression (4) with respect to γ. □

We see that introducing prominent and non-prominent software has two effects on platforms' pricing strategies. Firstly, platforms may subsidize prominent software developers which has also been shown in Rasch and Wenzel (2013). This can be optimal for a platform as users care about the amount of prominent software such that it influence users' adoption decisions. This is not the case for non-prominent software so that it is optimal to charge a strictly positive license fee toward these non-prominent developers. Secondly, platforms charge lower user prices the larger is the mass of prominent software. This is because platforms earn less from prominent than from non-prominent developers. Hence, the opportunity costs of attracting an additional user are lower when γ is high. In turn, user prices are lower with γ.

The following proposition evaluates the impact of software protection on equilibrium license fees:

Proposition 3. (i) The license fees charged to prominent and non-prominent software developers increase with the level of software protection. (ii) This effect is stronger for prominent software developers.

Proof. Ad (i): $\partial l^*/\partial k > 0$ as ϕ is increasing in k and θ is decreasing in k. $\hat{\partial} l^*/\partial k > 0$ as $\hat{\phi}$ is increasing in k. Ad (ii): it must be shown that $\partial l^*/\partial k > \hat{\partial} l^*/\partial k$. To this end, define $\check{k} := 3\alpha(1-\alpha)\beta/(2(1-\alpha)+\beta(5\alpha-1))$ and note that $\check{k} > \bar{k}$. It holds that $\partial l^*/\partial k > \hat{\partial} l^*/\partial k$ for all $k < \check{k}$ and hence, for all $k < \bar{k}$. □

As the proposition highlights, license fees for both types of developers increase with the level of software protection. This is also one finding in Rasch and Wenzel (2013). However, what is new is that the license fee for prominent developers increases to a larger extent due to a decreased subsidization

by the platform. There are two effects at work. Firstly, a higher level of software protection increases developers' immediate revenues from software sales to users so that platforms can extract more rents from developers and consequently increase the license fee. This effect applies to both types of developers. Secondly, with stricter software protection, users value additional software less inducing platforms to compete less hard for developers which induces platforms to increase license fees for prominent developers even further. This second effect of software protection applies only to prominent developers as only they are important for users' adoption decisions.

Equilibrium platform profits amount to

$$\Pi^* = \frac{\tau}{2} - \frac{3\gamma\theta\phi}{8} - \frac{\gamma\left(\theta^2+\phi^2\right)+(1-\gamma)\hat{\phi}^2}{16},$$

whereas the profits (net of developing costs) of prominent and non-prominent software firms are given by

$$\pi^* = \frac{\theta+\phi}{4}, \tag{5}$$

and

$$\hat{\pi}^* = \frac{\hat{\phi}}{4}. \tag{6}$$

We now evaluate the impact of software protection on firms' profits. Let $\tilde{k} := \alpha(1-\alpha)/(3+\alpha)$. Then, we obtain the following result:

Proposition 4. (i) Prominent software firms are hurt by a higher level of software protection if $k < \tilde{k}$ and benefit from a higher level of software protection if $k > \tilde{k}$. (ii) Non-prominent software firms benefit from a higher level of software protection. (iii) Non-prominent developers benefit from a higher level of software protection to a larger extent than prominent developers.

Proof. Ad (i): differentiating expression (5) with respect to k and solving yields $\tilde{k}$. It follows that $\partial\pi^*/\partial k \gtrless 0 \Leftrightarrow k \gtrless \tilde{k}$. Ad (ii): differentiating expression (6) with respect to k is always positive as $\partial\hat{\phi}/\partial k > 0$. (iii) It needs to be shown that $\partial\hat{\pi}^*/\partial k > \partial\pi^*/\partial k$. Note that $\partial\hat{\pi}^*/\partial k > \partial\pi^*/\partial k \Leftrightarrow$

$\partial\hat{\phi}/\partial k - \partial\phi/\partial k > \partial\theta/\partial k$. It holds that $\partial\hat{\phi}/\partial k > \partial\phi/\partial k$ and $\partial\theta/\partial k < 0$. Hence, $\partial\hat{\pi}^*/\partial k > \partial\pi^*/\partial k$. □

The proposition shows that prominent and non-prominent software developers may be affected quite differently by piracy and software protection. A higher level of software protection is favorable for non-prominent software developers but may be to the detriment of prominent ones. In other words, while prominent firms may appreciate more piracy, non-prominent firms are indeed always hurt by piracy.

With more software protection, both types of software firms benefit from an increase in legal sales to the same extent. The difference, however, stems from the different pricing strategies by platforms toward these two groups. With more software protection, platforms increase the license fee towards both types of developers; however, the increase towards prominent developers is larger (see Proposition 3).

Now if users' fixed cost of piracy—starting from a low level—increases, the immediate positive effect with respect to sales revenues is outweighed by the relatively higher license fees which leads to a decrease in profits for established developers (Rasch and Wenzel, 2013). In this case, users rarely purchase the legal version and hence developers make only low profits from users. In order to nevertheless secure developers' platform participation, platforms compete hard to be attractive for users and therefore end up subsidizing developers. As users start to purchase legal copies due to higher costs for owning an illegal copy, the need for developer subsidization is strongly reduced because at the same time, a larger number of developers due to higher sales relaxes the competition on the user side. As a consequence, platforms have a strong incentive to cut subsidies to developers. Note that for high levels of software protection, there is less or no subsidization which weakens the above effects.

As a result, for prominent software developers, the negative effect of an increase in the license fee may not be compensated by the positive effect of higher legal sales whereas for non-prominent software developers facing lower increases in license fees, the increase in legal sales is always the dominating effect.

It is noteworthy that the effect of piracy is always relatively more positive for prominent than for non-prominent software developers (see part (iii) of Proposition 4). Even in the case where the overall effect of piracy is negative for prominent developers (that is, prominent developers benefit from more software protection), these developers are at least partially compensated by lower license fees which is less the case for non-prominent software developers. Or put in other words, non-prominent software always benefit from stricter software protection to a larger extent.

Existing studies have provided several explanations why developers of digital media products may actually benefit from piracy. For instance, it has been shown that piracy may benefit developers in the presence of network externalities (Conner and Rumelt, 1991; Shy and Thisse, 1999; Peitz, 2004), complementary products (Gayer and Shy, 2006; Dewenter et al., 2012), sampling (Peitz and Waelbroeck, 2006), or two-sided business models (Rasch and Wenzel, 2013). This paper qualifies these results. The message is that it is important to take developer heterogeneity into account as the effects of piracy are likely to be heterogeneous across developers. Hence, this paper provides an explanation why developers within an industry may have quite different stands toward software protection and piracy.

As a final point we point out that, as in Rasch and Wenzel (2013), also the impact of software protection on platform profits is ambiguous. There are two counteracting forces. Competition for users may be intensified and competition for developers relaxed and either effect can dominate.

4 Extensions

In this section, we consider two extensions to the baseline model. For tractability, in these extensions, we focus on the case $\beta = 1$, so that the only difference between prominent and non-prominent software lies in the different impact on users' adoption decisions. With $\beta = 1$, this implies $\hat{\phi} = \phi$ and $\hat{\theta} = \theta$.

4.1 Prominence

In the base model, we have assumed that there are two groups of software developers: prominent and non-prominent developers. In this section, we relax this assumption.

Suppose there are N groups of developers. Each group of developers $h = 1, \ldots, N$ is characterized by ω_h which denotes the probability that software from this group is taken into account by users when making the adoption decision. Thus, ω_h serves as an indicator for the prominence of a particular piece of software. Without loss of generality, suppose $\omega_1 > \omega_2 > \ldots > \omega_N$. The fraction of developers in group h is $\gamma_h \in (0, 1)$ with $\sum_h \gamma_h = 1$.[17] We still assume that platforms can set a different license fee to each group.[18]

With h groups of developers, a user's perceived utility at the decision stage is

$$u_1 = v + \sum_h \omega_h \theta_h n_{h,1} - p_1 - \tau x$$

and

$$u_2 = v + \sum_h \omega_h \theta_h n_{h,2} - p_2 - \tau(1 - x).$$

The profits of platform i read as

$$\Pi_i = s_i p_i + \sum_h n_{h,i} l_{h,i},$$

and the profit of developer of type h on platform i is

$$\pi_h = \phi_h s_i - l_{h,i} - f.$$

As in the base model investment costs are uniformly distributed on the unit interval.

It can then be shown that the license fee group h is charged is given by

$$l_h^* = -\frac{\omega_h \theta - \phi}{4}.$$

[17] The base model analyzed in Section 3 is the special case with two groups ($N = 2$) where $\omega_1 = 1$, $\omega_2 = 0$, $\gamma_1 = \gamma$, and $\gamma_2 = 1 - \gamma$. Moreover, $\beta = 1$.

[18] We will later explore the consequences of lifting this assumption.

The license fee is the lower the more prominent a piece of software is, that is, $dl^h/d\omega^h < 0$ as platforms are competing harder to attract those developers that are important for users' adoption decisions. The profit of a developer of group h is:

$$\pi_h^* = \frac{\omega_h \theta + \phi}{4}. \tag{7}$$

The following proposition evaluates the impact of software protection on software developers' profits. Let $\tilde{k}(\omega_h) = \alpha(1-\alpha)(3\omega_h - 2)/(2(1-\alpha) + \omega_h(1+3\alpha))$.

Proposition 5. (i) A developer of type h is hurt by a higher level of software protection if $k < \tilde{k}(\omega_h)$ and benefits if $k > \tilde{k}(\omega_h)$. (ii) The higher is the level of prominence, the smaller is the parameter range where a developer benefits from increased software protection.

Proof. Ad (i): differentiating expression (7) with respect to k and solving yields the critical value $\tilde{k}(\omega_h)$. Ad (ii): by differentiation, it follows that $\partial\tilde{k}(\omega_h)/\partial\omega_h > 0$. □

Proposition 5 demonstrates that the more prominent a firm is, the more likely it is that this developer benefits from piracy and thus favors a low level of software protection. All developers, independent of their degree of prominence, benefit from an increase in legal sales if software protection is high. However, developers are hurt by the increase in the license fees. This effect is more pronounced for more prominent than for less prominent firms. Hence, only for the most prominent firms, the increase in legal revenues is consumed by the increase in the license fee. The effect of stricter software protection becomes more and more negative the more prominent a developer is.

4.2 Uniform license fee

In the base model, we have assumed that platforms can price-discriminate between prominent and non-prominent software developers. This requires

that platforms have a good knowledge of which software products are important for users' adoption decisions. For many circumstances, this seems to be a quite reasonable assumption. In other circumstances, however, the distinction between prominent and non-prominent software products may be less obvious and price discrimination may not be feasible. In particular, price discrimination becomes less easy if there are many different groups as in the preceding section. This section discusses the impact of piracy on developers when platforms cannot set different license fees for prominent and non-prominent software developers but are required to set a uniform license fee to both types of developers.

It can be shown that the license fee for all developers is set at

$$l^* = -\frac{\gamma\theta - \phi}{4}$$

so that each developer earns profits of

$$\pi^* = \frac{\gamma\theta + \phi}{4}. \tag{8}$$

Let $\tilde{k}(\gamma) := \alpha(1-\alpha)(3\gamma-2)/(2(1-\alpha)+\gamma(1+3\alpha))$, we obtain the following result:

Proposition 6. (i) Software developers are hurt by a higher level of software protection if $k < \tilde{k}(\gamma)$ and benefit if $k > \tilde{k}(\gamma)$. (ii) The higher is the share of prominent developers (γ), the smaller is the parameter range where a developer benefits from increased software protection.

Proof. Ad (i): differentiating expression (8) with respect to k and solving yields the critical value $\tilde{k}(\gamma)$. Ad (ii): by differentiation, it follows that $\partial\tilde{k}(\gamma)/\partial\gamma > 0$. □

Proposition 6 shows that software developers can also be hurt by stricter software protection if software platforms are not able to set different license fees for prominent and non-prominent developers. In this case, also non-prominent developers may benefit from a lower level of software protection. They benefit from the presence of prominent developers and platforms' inability to price-discriminate.

5 Conclusion

This paper analyzes piracy in software markets that are characterized by two-sided network externalities. This issue is gaining in importance as an increasing number of software markets are organized as two-sided business models (e.g., smartphone applications, e-books), and piracy appears to be a growing concern in those markets.

This paper argues that taking firm heterogeneity into account is an important factor when evaluating the effects of software piracy in such markets. In this paper, we develop a model with imperfect consumer behavior where consumers only consider prominent software when choosing between competing platforms. We find that even though prominent pieces of software suffer from higher piracy rates, contrary to conventional wisdom, this does not necessarily mean that higher software protection benefits those firms. We show that relatively well-known products may indeed benefit from a low level of software protection whereas less known software products are hurt. The key to this result is that (i) there is tougher platform competition for prominent than for non-prominent developers and (ii) competition for prominent developers intensifies in the presence of low software protection so that license fees are reduced heavily for prominent software developers.

This paper also raises issues for further research. In this paper, we propose prominence as one potential reason why developers may have different attitudes towards piracy. On the theory side, future research could identify alternative sources of heterogeneity that might also explain the different stances towards piracy. On the empirical side, our paper invites research that assesses the effects of piracy on different firm types or different industries. It would be valuable to evaluate which type of software firm benefits/loses from piracy and how different firm characteristics affect those results since our model suggests that the effects might be heterogenous across firms and/or industries.

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