Open Versus Closed Platforms in Two-sided Markets

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Abstract

This paper studies an industry in which firms can choose to provide open or closed platforms. Open platforms, as opposed to closed, are extendable so third-party producers can develop extensions for them. Building on a two-sided market model, I show that firms might prefer to commit to keeping their platforms closed despite the fact that opening the platform is costless and open platforms are more valuable to consumers. The reason is that an open platform leads to intensified competition for consumers.

Keywords: Platforms; Software; Two-sided markets.

JEL Codes: D40; D42; D43; L10; L12; L13; L14.

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1 Introduction

Why are some platforms open to third-party development while others are closed? In this paper I take a two-sided market approach and highlight that the choice may involve a trade-off between benefits from an open platform and intensified competition for consumers. I show that firms might prefer to commit to keeping their platforms closed despite the fact that opening the platform is costless and open platforms are more valuable to consumers. The choice between supplying an open versus a closed platform is relevant in a number of markets. For example, operating systems for modern personal computers are prime examples of open platforms. Apple's OS X, Microsoft's Windows Vista and various versions of Linux all allow for, and encourage, application development. The same holds for video game consoles. As of 2008, the three big consoles on the market (the Xbox360, the Playstation 3 and the Wii) are all sold as open platforms with third-parties developing games for the consoles. But there also exists a sea of cheaper closed consoles that come with one or several games pre-installed (such as Sudoku or Tetris). In some markets the same firm might provide both open and closed platforms. For example, high-end phones usually come installed with an open operating system that allows for third-party applications. The Nokia N95 comes with the S60 software that permits users to install software from third-party application developers. Cheaper mobile phones, such as the Nokia 1600, are often closed and does not have the ability to install applications. Interestingly, when Apple entered the mobile phone market in June 2007 with the iPhone, they entered with a closed platform. Native third-party application development was impossible for the phone, upsetting developers that had become used to open high-end phones. Apple has, however, announced that third-party application development will be possible for the iPhone in June 2008.[1] Finally, some markets shift from open to closed over time. In enterprise software, for example, there seems to have been a shift towards closed platforms. The following account is from Arora and Bokhari (2007): *"In enterprise software, for instance, SAP offers a closed product (an integrated suite, to use the industry term), with various application modules designed to work with the basic SAP enterprise resource planning (ERP) platform. Instead, until recently, users could opt for an Oracle database platform, using applications from Peoplesoft for human resources, JD Edwards for financial management, Siebel for customer relationship management and so on. In the last couple of years, all of these companies were acquired by Oracle, and it is likely that in the future, it will offer an integrated suite as well, so that we might see only competing closed systems in this market."*

I am naturally not the first one to analyze the choice between supplying

[1] http://www.apple.com/pr/library/2008/03/06iphone.html. Accessed March 2008.

an open versus a closed platform. The concept of open and closed platforms has been interpreted in different ways in the literature. Schiff (2003) analyzes open and closed systems of two-sided networks, referring to compatibility between two platforms (e.g. if applications developed for one platform works with the other). Hagiu (2007b) analyzes open versus proprietary platforms, in which an open platform indicates that prices are zero on both sides. In the sense of open and closed platforms referring to third-party access to the platform, Kende (1998) compares profitability of open versus closed systems. He departs from the literature on aftermarkets.[2] A firm can sell an open platform for a high price and encourage competition and cheap provision of extensions by third-parties in an aftermarket when consumers have already bought the platform. Alternatively, the firm could sell a cheap closed platform and itself provide extensions at monopoly price in the aftermarket. Kende (1998) shows that an open system is more profitable when demand for the system is more elastic, secondary component variety is more valued and when the main component has a large share of consumers budget. Matutes and Regibeau (1988) study mix and matching of components.[3] Compatibility (open platforms) allows consumers to mix and match components from two competing firms. Incompatibility (closed platforms) force consumers to buy both components from the same firm. The authors show that industries should tend towards compatibility, because compatibility shifts the industry demand curve upwards and relaxes price competition. Church and Gandal (2000) introduce a taste for variety in secondary components in their study of hardware and software systems. Closing the system implies integration into the secondary component and enforcing incompatibility with the other component. The profitability of closing the system depends on a trade-off between profits from selling software produced in-house, and profit increases from selling more hardware when there is more variety of software provided by third-parties. Arora and Bokhari (2007) build a dynamic model of open versus closed systems. They emphasize that firms may differ in their costs of producing different components. Open firms can specialize in producing one component. Closed firms cannot, and must produce both components. In the long run, the trade-off is between diseconomies of scope (in favor of open systems) and costs of transacting across firm boundaries (in favor of closed systems).

On a theoretical basis, and in contrast to the above mentioned papers, I build on the existing literature on two-sided markets.[4] I start from a stylized two-sided market model that builds on Armstrong (2006) and I endogenize the choice of operating in a one-sided (closed) or a two-sided (open) market. Much of the early literature on two-sided markets is focused on solving

[2] See also Shapiro (1995) and Borenstein and MacKie-Mason (2000).

[3] See also Economides (1989).

[4] See for example Rochet and Tirole (2003), Caillaud and Jullien (2003), Rochet and Tirole (2006), Hagiu (2006) and Armstrong (2006).

the problem of how much to charge each side. Related to comparing one and two-sided markets, there has been some work on the difference between operating as a merchant versus operating as a platform. According to Hagiu (2007a), the main difference is that a merchant takes full possession of the content, whereas a platform leaves control over the sale to sellers and simply intermediates the transaction. Work on exclusivity in two-sided markets by Hagiu and Lee (2007) and Lee (2007) is also related. In their model a content provider joins one or both platforms depending on if the content is exclusive or not. In contrast to these studies, I compare a two-sided platform to a one-sided platform with "the other side" completely left out. My focus is also different as I mainly examine the effect of competition between platforms on the choice of providing an open or a closed platform.

In taking the two-sided market route, my approach is different from Kende (1998) in that I assume away the central hold-up problem in the aftermarket literature. Instead, I focus on the ability of firms to charge (or subsidize) third-parties for the right to develop applications for the platform. Adding this dimension, the firms can profit directly from selling rights to develop for the platform. They also have the ability to subsidize developers to encourage application development. I mainly differ from the components versus systems approach in Matutes and Regibeau (1988), Church and Gandal (2000) and Arora and Bokhari (2007) by analyzing atomistic producers of secondary components instead of two (or more) components produced by the same (or by different) firms. I put heavy emphasis on the existence of cross-group externalities between consumers and application developers. Further, I completely "black box" the pricing decision of application developers. The benefit of my analysis is a new perspective emphasizing cross-group externalities and platform pricing to internalize them. The drawback is that I assume away potentially important strategic interactions between the price of the platform and the price of applications set by application developers.

2 The Model

I study a two-stage duopoly model of a two-sided market where software platforms connect consumers with third-party application providers. There are two platforms, $k \in \{1, 2\}$, each of the same intrinsic value v. The value of any applications developed in-house by the platform is also included in v. The number of these applications is assumed to be exogenous and independent of the platform being open or closed. For example, the same basic set of applications (such as a calendar, a phone book, alarm clock, a simple game) bundled with a high-end open phones are also often available on closed low-end phones. When Apple introduced the closed iPhone, the set of built in applications resembled the basic set of applications bundled with other competing high-end phones. The platforms can be open, in which case they connect consumers with application developers, or they can be closed and simply sell the platform of value v to consumers. If open, the platforms can set a fee (or subsidy) for the right to develop an application. Costs for opening the platform are zero. Fixed costs are sunk and marginal costs zero. Consumers buy only one platform, but application developers may develop for any or both of the open platforms.

2.1 Consumers

The consumers are uniformly distributed on the unit interval with the platforms located at the endpoints of the interval. The intrinsic quality of the platforms, v, is large enough so the market is completely covered.[5] The platforms differ in the eyes of consumers only in price and in the number of applications available. A consumer denoted by i receives utility

$$u_{i1} = (v - tx_i) + bn_{a1} - p_1, \tag{1}$$

if buying platform 1 and utility

$$u_{i2} = (v - t(1 - x_i)) + bn_{a2} - p_2, \tag{2}$$

if buying platform 2. The number of applications available at platform 1 and 2 are given by n_{a1} and n_{a2}. The parameter $b > 0$ measures the additional value of the platform for each third-party application available. Platform prices are p_1 and p_2. The transportation cost parameter, t, measures the degree of horizontal differentiation between the platforms.

2.2 Application Developers

The application developers are independent monopolists. They are treated as atomistic and are uniformly distributed on the unit interval, $y \in [0, 1]$. A developer's location index fixed costs for coming up with a business idea, setting up shop, and developing an application. The costs of developing applications is scaled by f. An application developer indexed by y_j has fixed costs equal to fy_j for developing an application. Each application developer is able to extract an expected profit of $a > 0$ from each consumer purchasing the platform. These profits are generated from sources such as selling advertising space or increased sales from complementary products.

Application developers are allowed to multi-home. This means that they may develop applications for both platforms. If both platforms are open, application developers make the decision to develop for one platform independently from the decision to develop for the other platform. There is thus

[5] The condition needed when both platforms are closed is $v > \frac{3t}{2}$. When both firm provide open platforms the condition is $v > \frac{6ft - a^2 - 3ab}{4f}$. When one platform is closed and the other is open the conditions are $abf(9t - 4v) > a^3b + f(6ft(3t - 2v) + b^2v) + a^2(b^2 + f(v - 3t))$ and $f(b^2(3t - v) + 6ft(2v - 3t)) > a(a^2b + 2ab^2 + b^3 - 3aft - 12bft + (a + 4b)fv)$.

no direct competition between the firms for developers. A firm can attract more developers by either lowering the price of the platform, thereby selling to more consumers, or by reducing the fee or increasing the subsidy for application development. Application developers must pay the fixed development cost twice if they wish to supply an application for both platforms. Conditional on the number of consumers at each platform, an application developer j has profits equal to

$$\pi_{jk} = an_{ck} - fy_j - s_k \tag{3}$$

from each platform $k \in \{1, 2\}$. The costs of developing applications are high enough to ensure that some developers always stay out of the market.[6] The parameter s_k denote the fee or subsidy imposed or handed out by the platform. If s is positive, it represents a fee that must be paid for the right to develop an application. An example is a fee that must be paid for an application development kit needed to create the application. If s is negative it is a subsidy. It can then be any type of action by the firm operating the platform that lowers the costs of developing an application, such as training, subsidized conferences and free extensive documentation of interfaces.

2.3 Timing

- In stage 1, the platforms simultaneously decide if they should be open or closed. Figure 1 illustrate possible outcomes.
- In stage 2, the platform observe the choice the rival made. They then simultaneously set price to consumers. The platforms that are open also set the fee or subsidy to application developers. Consumers and developers then observe prices and the fees or subsidies. They form fulfilled expectations regarding the participation of the opposite group. Then consumers buy the platform yielding the highest utility and developers decide for each platform separately if they should develop for the platform.

This timing captures that the choice of providing a closed or an open platform is more long term than price and fee (subsidy) choices. It allows firms to commit to providing an open or a closed platform before setting prices and fees. In what follows, I solve this game by backwards induction. I look for pure strategy sub-game perfect Nash equilibria. I start by analyzing pricing in the second stage of the game. I consider separately all of the four sub-games outlined in figure 1. I then move back to the first stage of the game and analyze the choice between providing an open or a closed platform.

[6] The assumptions needed are $f > \frac{a+b}{4}$ when the platforms are open and $f(a^2 + 4ab + b^2 + 3(a + b - 4f)t) < ab(a + b))$ when one platform is open and the other is closed.

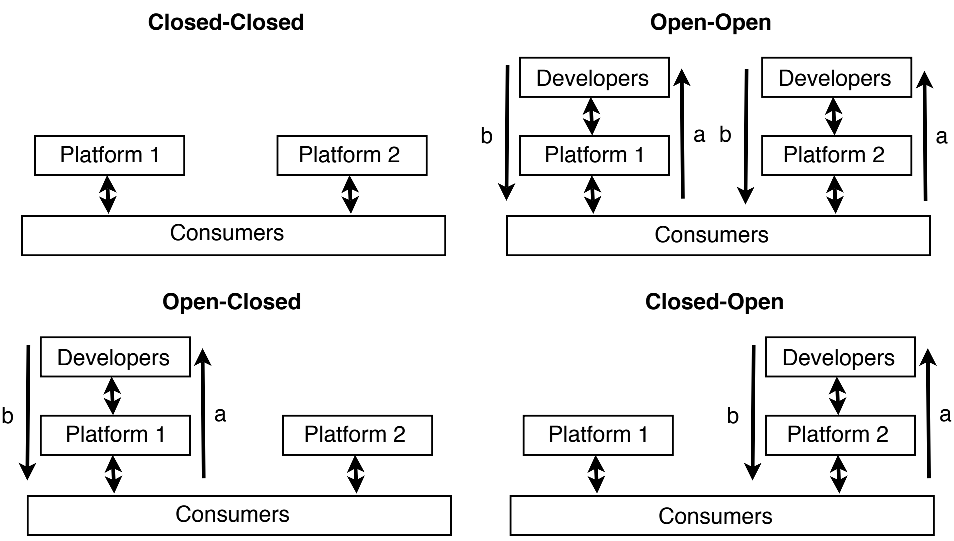

Figure 1: In stage 1 firms choose between providing an open or providing a closed platform. Their choices give rise to these sub-games in stage 2.

3 Solving the Model

3.1 Stage 2: Closed-Closed

When both platforms are closed, the setup reduces to the standard Hotelling model with firms at both endpoints of the unit interval. For the consumer indifferent between purchasing the platform from firm 1 or firm 2, $v - tx_i - p_1 = v - (1-t)x_i - p_2$ holds. Then demand for firm 1's platform is equal to $n_{c1} = \frac{1}{2} + \frac{p_2 - p_1}{2t}$. Demand for firm 2's platform is equal to $n_{c2} = 1 - n_{c1}$. The firms simultaneously set price to consumers to maximize

$$\pi_{kCC} = p_k n_{ck}. \tag{4}$$

This results in equilibrium prices of $p^*_{kCC} = t$, and profits of $\pi^*_{kCC} = \frac{t}{2}$. The second order conditions, $-\frac{1}{t} < 0$, are satisfied. Prices and profits are decreasing in the intensity of competition between the firms.

3.2 Stage 2: Open-Open

The consumer indifferent between purchasing platform 1 and purchasing platform 2 is now located the x_i that satisfies $v + bn_{a1} - tx_i - p_1 = v + bn_{a2} - (1-t)x_i - p_2$. Demand for firm 1's platform conditional on the number of applications at each platform is then equal to $n^{cond}_{c1} = \frac{1}{2} + \frac{bn_{a1} - bn_{a2}}{2t} + \frac{p_2 - p_1}{2t}$. Demand for firm 2's platform conditional on the number of applications at each platform is $n^{cond}_{c2} = 1 - n^{cond}_{c1}$. The developer indifferent between developing an application for platform k and not developing one is located at $y_j = \frac{an_{ck}-s_k}{f}$. Demand for developing applications for platform k conditional on the number of consumer purchasing each platform is then $n_{ak}^{cond} = \frac{an_{ck}-s_k}{f}$. To obtain demands as functions of prices on both sides of the market I simultaneously solve the equations $n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$, $n_{a1} = n_{a1}^{cond}$ and $n_{a2} = n_{a2}^{cond}$ to obtain

$$n_{c1}(p_1, p_2, s_1, s_2) = \frac{b(s_2 - a - s_1) + f(p_2 - p_1 + t)}{2(ft - ab)}, \tag{5}$$

$$n_{c2}(p_1, p_2, s_1, s_2) = \frac{b(s_1 - a - s_2) + f(p_1 - p_2 + t)}{2(ft - ab)}, \tag{6}$$

$$n_{a1}(p_1, p_2, s_1, s_2) = \frac{a(b(s_1 + s_2) + f(p_2 - p_1 + t)) - a^2 b - 2fs_1 t}{2f(ft - ab)}, \text{ and} \tag{7}$$

$$n_{a2}(p_1, p_2, s_1, s_2) = \frac{a(b(s_1 + s_2) + f(p_1 - p_2 + t)) - a^2 b - 2fs_2 t}{2f(ft - ab)}. \tag{8}$$

The firms simultaneously set prices, p_k, to consumers and the fees(subsidies) to application developers, s_k, to maximize

$$\pi_{kOO} = p_k n_{ck}(p_1, p_2, s_1, s_2) + s_k n_{ak}(p_1, p_2, s_1, s_2). \tag{9}$$

Equilibrium prices are

$$p_{kOO}^* = t - \frac{a(a + 3b)}{4f} \text{ and } s_{kOO}^* = \frac{a - b}{4}, \tag{10}$$

and platform profits are

$$\pi_{kOO}^* = \frac{t}{2} - \frac{a^2 + 6ab + b^2}{16f}. \tag{11}$$

The second order conditions, $-\frac{f}{ft-ab} < 0$, $-\frac{2ft-ab}{f(ft-ab)} < 0$, and $\frac{8ft-a^2-6ab-b^2}{4(ab-ft)^2} > 0$ are satisfied for $4ft - (a+b)^2 > 0$. Firms balance price to consumers with fees (or subsidies) to application developers so as to best internalize cross-group externalities. Application developers are subsidized if the valuation of applications by consumers is sufficiently large in relation to developers' profits from reaching one more consumer (if $b > a$). As Armstrong (2006) notes, profits from the multi-homing side (the application developer side) are competed away on the single-homing (consumer) side of the market. The reason is that competition for consumers is intensified when platforms are open. A cut in the price to consumers lead to more consumers buying the platform. It also attracts more application developers because more consumers bought the platform. Both platforms then have strong incentives to cut price to consumers. These incentives are increasing in the size of the cross-group externalities and decreasing in the costs of developing applications (because it becomes easier to attract developers). Hence, profits (and prices) are increasing in the costs of developing applications and decreasing in the size of the cross-group externalities.

3.3 Stage 2: Open-Closed and Closed-Open.

Assume firm 1 has the open platform and firm 2 has the closed platform. The formulas for the reverse case can easily be obtained by renaming the platforms. Conditional on the number of applications developed for platform 1, the consumer indifferent between the platforms is located at the x_i that satisfies $v+bn_{a1}-tx_i-p_1 = v-(1-t)x_i-p_2$. Demand for platform 1 conditional on the number of application developers that develop for platform 1 is $n_{c1}^{cond} = \frac{1}{2}+\frac{bn_{a1}}{2t}+\frac{p_2-p_1}{2t}$. Demand for platform 2 conditional on the number of application developers that develop for platform 1 is $n_{c2}^{cond} = 1-n_{c1}^{cond}$. The developer indifferent between developing for platform 1 and not developing is located at $y_j = \frac{an_{c1}-s_1}{f}$. Demand for developing applications for platform 1 conditional on the number of consumers purchasing platform 1 is then $n_{a1}^{cond} = \frac{an_{c1}-s_1}{f}$. To obtain demands as functions of prices on both sides of the market, I simultaneously solve the equations $n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$ and $n_{a1} = n_{a1}^{cond}$. This gives

$$n_{c1}(p_1,p_2,s_1) = \frac{bs_1+f(p_1-p_2-t)}{ab-2ft}, \tag{12}$$

$$n_{c2}(p_1,p_2,s_1) = \frac{ab-bs_1-f(p_1-p_2+t)}{ab-2ft}, \text{ and} \tag{13}$$

$$n_{a1}(p_1,p_2,s_1) = \frac{a(p_1-p_2-t)+2s_1t}{ab-2ft}. \tag{14}$$

Firm 1 sets price to consumers and the fee (or subsidy) to application developers to maximize

$$\pi_{1OC} = p_1 n_{c1}(p_1,p_2,s_1) + s_1 n_{a1}(p_1,p_2,s_1). \tag{15}$$

Firm 2 simultaneously sets price to consumers to maximize

$$\pi_{2OC} = p_2 n_{c2}(p_1,p_2,s_1). \tag{16}$$

Equilibrium prices are

$$p_1^* = \frac{(4ft-a(a+b))(3ft-ab)}{f(12ft-a^2-4ab-b^2)}, \tag{17}$$

$$s_1^* = \frac{(a-b)(3ft-ab)}{12ft-a^2-4ab-b^2}, \text{ and} \tag{18}$$

$$p_2^* = \frac{(6ft-(a+b)^2)(2ft-ab)}{f(12ft-a^2-4ab-b^2)}. \tag{19}$$

Platform profits are

$$\pi_{1OC}^* = \frac{(8ft-(a+b)^2)(ab-3ft)^2}{f(a^2+4ab+b^2-12ft)^2}, \text{ and} \tag{20}$$

$$\pi_{2OC}^* = \frac{((a+b)^2-6ft)^2(2ft-ab)}{f(a^2+4ab+b^2-12ft)^2}. \tag{21}$$

		Firm 2	
		C	O
Firm 1	C	$(\pi^*_{1CC}, \pi^*_{2CC})$	$(\pi^*_{1CO}, \pi^*_{2CO})$
	O	$(\pi^*_{1OC}, \pi^*_{2OC})$	$(\pi^*_{1OO}, \pi^*_{2OO})$

Figure 2: The simultaneous game played in stage 1.

The second order conditions -$\frac{2f}{2ft-ab} < 0$, $-\frac{4t}{2ft-ab} < 0$ and $\frac{8ft-(a+b)^2}{(ab-2ft)^2} > 0$ are satisfied for $4ft - (a+b)^2 > 0$. By reversing the identities of the platforms, we can get profits under the outcome Closed-Open. These profits are $\pi^*_{1CO} = \pi^*_{2OC}$ and $\pi^*_{2CO} = \pi^*_{1OC}$. Application developers are subsidized if $b > a$. The size of cross-group externalities and the costs of developing applications can either increase or decrease profits. The reason is that while cross-group externalities benefit the platform, they also lead to intensified competition for consumers.

3.4 Stage 1: Open or Closed?

The firms simultaneously decide if third-parties should be able to develop for their platform. The game played in stage 1 is summarized in figure 2. By solving the first stage, we can obtain the following proposition.

Proposition 1. *For sufficient difference in cross-group externalities both firms provide open platforms. They are trapped in a prisoners dilemma. If the difference in cross-group externalities is small enough, both firms provide closed platforms. For intermediate differences in cross-group externalities one platform is open and one is closed.*

Proof. First, assume that it is desirable for firm 1 to offer an open platform if firm 2 offers a closed platform. Then $\pi^*_{1OC} > \pi^*_{1CC}$ or $\frac{(8ft-(a+b)^2)(ab-3ft)^2}{f(a^2+4ab+b^2-12ft)^2} > \frac{t}{2}$. Simplifying, using $4ft - (a+b)^2 > 0$, leads to the following condition $2a^2b^2+(a^2-6ab+b^2)ft > 0$. Note that this condition holds if $a^2-6ab+b^2 > 0$ or equivalently if $(a-b)^2 - 4ab > 0$ (sufficient difference in cross-group externalities). Assuming that $a^2 - 6ab + b^2 > 0$, it is possible to show that $\pi^*_{1OO} > \pi^*_{1CO}$ or that $\frac{8ft-a^2-6ab-b^2}{16f} > \frac{((a+b)^2-6ft)^2(2ft-ab)}{f(a^2+4ab+b^2-12ft)^2}$. Then firm 1 has a dominant strategy to open the platform. This holds for firm 2 as well. Hence, the pure strategy Nash equilibrium is for both firms to provide open platforms. The equilibrium is shown in area 1 in figure 3. Since $a^2 + 6ab + b^2 > 0$, it must be that $\pi^*_{1CC} > \pi^*_{1OO}$ and the game is a prisoners dilemma.

Second, suppose now that $2a^2b^2 + (a^2 - 6ab + b^2)ft > 0$, but that $a^2 - 6ab + b^2 < 0$ (so ft is small). Then $\pi^*_{1OC} > \pi^*_{1CC}$, but it need not be that $\pi^*_{1OO} > \pi^*_{1CO}$. If instead $\pi^*_{1OO} < \pi^*_{1CO}$, then the game has two pure

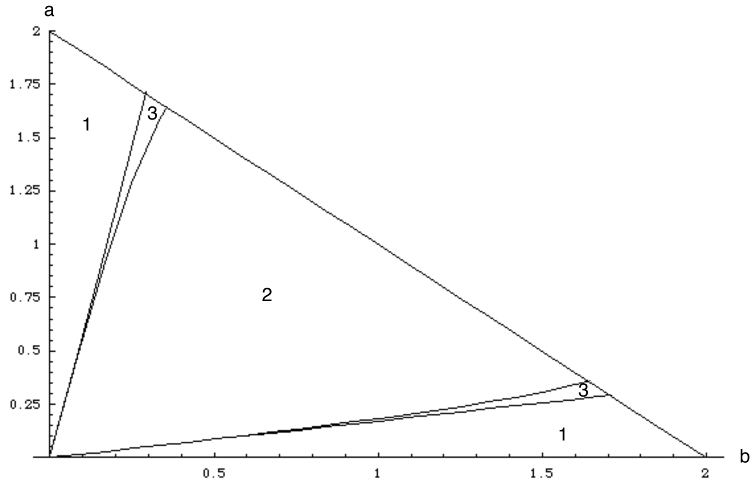

Figure 3: Equilibrium regions for $f = t = 1$. The line from (0,2) to (2,0) corresponds to $4ft - (a+b)^2 = 0$, the line separating area 1 and 3 to $(a-b)^2 - 4ab = 0$ and the line separating area 2 and 3 to the equation $2a^2b^2 + (a^2 - 6ab + b^2)ft = 0$. Varying f or t scales the picture.

strategy Nash equilibria. Either firm 1 provides an open platform and firm 2 provides a closed or the reverse holds. Equilibria of this type must lie in area 3 in figure 3, but area 3 also contain parameter combinations resulting in an equilibrium characterized by both platforms being open.

Third, assume now that it is desirable for firm 1 provide a closed platform is firm 2 provides a closed platform. Then $2a^2b^2 + (a^2 - 6ab + b^2)ft < 0$ and it is possible to use this to show that $\pi^*_{1CO} > \pi^*_{1OO}$. Then firm 1 has a dominant strategy to say closed. This also holds for firm 2 and the pure strategy Nash equilibrium is for both firm to provide closed platforms. Parameter combinations in area 2 in figure 3 characterize this equilibrium. □

The proposition highlights that firms may have a dominant strategy to remain closed, despite the fact that opening the platform is free and consumers value an open platform higher than a closed platform. The reason for this is tied to the nature of the quality increase. The quality increase in the platform that arise when the platform is open depends indirectly on the number of consumers purchasing the platform. This is an important difference to a quality increase in the intrinsic value of the platform (v). All else equal, a given price cut to consumers when open attracts more new consumers compared to when closed because price is lower and platform quality is higher. To see this formally, we can examine the best response functions of firm 1. The best response functions for price for firm 1 when its platform is closed are

$$p_1(p_2)_{CC} = \frac{t+p_2}{2}, \text{ and} \tag{22}$$

$$p_1(p_2, s_2)_{CO} = \frac{t+p_2}{2} - \frac{b(a-s_2)}{2f}. \tag{23}$$

When firm 1 provides an open platform the best response functions are

$$p_1(s_1, p_2)_{OC} = \frac{t+p_2}{2} - \frac{(a+b)s_1}{2f}, \text{ and} \tag{24}$$

$$p_1(s_1, p_2, s_2)_{OO} = \frac{t+p_2}{2} - \frac{(a+b)s_1}{2f} - \frac{b(a-s_2)}{2f}. \tag{25}$$

Studying these, we can see that because $\frac{b(a-s_2)}{2f} > 0$ in equilibrium, firm 1 has incentives to price more aggressively if firm 2 provides an open platform. [7] Hence, by committing to providing closed platforms firms are able to reduce the intensity of competition for consumers.

In equilibrium, the effect on profits from opening the platform depends on a balance between a) benefits from an increase in the value of the platform and the possibility to profit from application developers and b) intensified competition for consumers. For a sufficiently similar to b, both firms have individual incentives to provide a closed platform. An open platform would lead to lower profits due to intense competition for consumers. This case is represented in area 2 in figure 3. If a is much larger than b, acquiring additional consumers is very profitable for the firm as the fee for the right to develop applications can be substantially increased. Even though competition for consumers is intensified with an open platform, the firm finds it profitable to open the platform because selling the rights to develop applications recoups losses from intensified competition for consumers. If b is much larger than a, the ability to subsidize application developers so as to increase the value of the platform for consumers makes it profitable to provide an open platform. The quality increase in the platform becomes sufficiently large so as to compensate for the effect of intensified competition. These two cases are represented by area 1 in figure 3. In both cases, the firms are trapped in a prisoners dilemma. They would be better of had they been able to collude in stage 1 on keeping the platforms closed. For intermediate differences in a and b, it may be that the platforms prefer to be open if the rival is closed and closed if the rival is open. In these cases profit increases from being open are enough to compensate for intensified competition only if the rival is closed, not if the rival is open. The reason is that competition is more intense when both firms are open than if only one is open. Area 3

[7] Note that firm 1 is either more or less aggressive in pricing when open. If $b > a$, so $s_1 < 0$ in equilibrium, firm 1 is less aggressive in pricing. If $b < a$, so $s_1 > 0$ in equilibrium, firm 1 is more aggressive in pricing.

in figure 3 contain such parameter combinations, but area 3 also contain parameter combinations in which the equilibrium is for both firms to provide open platforms. Finally, application development costs (f) and the intensity of competition between platforms (t) also affect the choice of providing an open versus a closed platform. Increased development costs for applications and decreases in the intensity of competition (increases in t) tend to make a closed platforms more likely due to diminished benefits from cross-group externalities. This can be seen by noting that if ft is large and the difference in the cross-group externalities small, it is more likely that $\pi^*_{1OC} < \pi^*_{1CC}$ and $\pi^*_{1CO} > \pi^*_{1OO}$ since it is more likely that $2a^2b^2 + (a^2 - 6ab + b^2)ft < 0$.

4 Conclusion

Why are some platforms open to third-party development while others are closed? In this paper I take a two-sided market approach and highlight that the choice may involve a trade-off between benefits from an open platform on one hand and intensified competition for consumers on the other. Providing an open platform is profitable because allowing third-party applications raise the value of the platform. A firm with an open platform can also either profit from selling the rights to develop applications, or subsidize developers to further increase the value of the platform. But opening the platform also makes the rival more aggressive in pricing. Firms might hence prefer to commit to keeping their platforms closed despite the fact that opening the platform is costless and open platforms are more valuable to consumers. I find three types of equilibrium configurations. Either both platforms are open (and the firms are trapped in a prisoners dilemma), both platforms are closed, or one platform is open and one is closed. The outcome depends on the relative difference in cross-group externalities, on the intensity of competition for consumers and on the cost of developing applications.

I have cast the model in the framework of software and hardware platforms. It could also apply to other two-sided markets in which choosing between providing a one-sided or a two-sided platform is possible. In particular, the analysis could be adopted to study media markets. A "closed" platform in this framework is a magazine or TV station without advertisements. An "open" platform has advertisements and is hence two-sided.

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