Competing Platforms and Third Party Application Developers

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Abstract: Technology firms often decide between being open or closed to third party application development. Building on a two-sided market model with competing platforms, I show that firms might prefer to restrict third party application development despite the fact that allowing it is free and increases the value of the product to consumers. The reason is that restricting third party application development removes network effects and thereby relaxes competition between platforms. From a social welfare perspective, firms sometimes restrict third party application development even though total welfare would be higher if development was possible.

Key words: platforms; software; two-sided markets.

> "Tech firms today are caught in a bind, between being open (to attract a community of developers) and closed (to ensure high standards and maintain their traditional business models)." *The Economist* [1]

Why are some products open to third party development while others are closed? As the quote above underscores, it may be a trade-off between having applications that raises the value of the product and ensuring a high quality product. I, however, take a two-sided market approach underscoring that being open to third party developers can lead to intensified competition for consumers. Hence, firms might prefer to restrict third party application development despite that allowing it is free and increases the value of the product to consumers.

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1 *The Economist*, "Who holds the key?", Aug 15th 2008 from Economist.com.

The choice between allowing and banning third party application developers is relevant in a number of markets. For example, operating systems for modern personal computers are prime examples of products that are open to third party application development. Apple's OS X, Microsoft's Windows Vista and various versions of Linux all allow for and even encourage application development. The same holds for video game consoles. The three large consoles on the market (the Xbox 360, the Playstation 3 and the Wii) have third parties developing games for them.

In some markets, the same firm provides products that both allow for and restrict third party development. High-end phones often have an operating system that allows for third party applications. The Nokia N95, for example, comes with the S60 software permitting users to install software from third party application developers. Yet, cheaper mobile phones such as the Nokia 1600 often restrict third party application development. Interestingly, when Apple entered the mobile phone market in June 2007 with the iPhone, third party application development was impossible for the phone. Apple, however, later reversed this strategy by releasing a software development kit for the iPhone in June 2008.

A related question is if firms allow third parties access to their products when it is socially desirable? This has been a concern for antitrust authorities. For example, in 1955, the FCC in the United States agreed with the AT&T Bell System that an attachment to phones (the Hush-A-Phone) that helped reduce noise could not be marketed and sold independently, since it was a "foreign attachment" to the AT&T network. The FCC also concluded that all telephone equipment should be sold by the network operator. However, this decision was overturned on appeal by the D.C. Circuit. In line with this appeal, the FCC later (in 1968) ruled that it should be possible to use another attachment, the Carterfone, on the AT&T Bell System network despite the fact that is was marketed by an independent company.

This paper contributes to the literature on systems, aftermarkets and two-sided markets by studying the decision to allow or restrict third party application development. I start from a standard two-sided market model from ARMSTRONG (2006) and I endogenize the choice of allowing one of the sides (application developers) to interact with the other (consumers).

Much of the early literature on two-sided markets focuses on solving the problem of how much to charge each side [2]. 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 (2007), 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.

There is also related work on exclusivity in two-sided markets by HAGIU & LEE (2007). In their model, a content provider joins one or both platforms depending on whether the content is exclusive or not. In contrast, I compare the platforms' choice of whether to allow third parties [3]. Finally, this paper is also related to the two-sided market literature discussing pay-tv versus free-to-air (see e.g. ANDERSON & COATE, 2005; PEITZ & VALLETTI, 2008; KIND, NILSSEN & SORGARD, 2005). The main contribution to this literature is that I consider platform competition with an endogeneous choice between being one-sided (pay-tv) and being two-sided (partly or fully advertising supported).

In taking the two-sided market route, my approach differs from the aftermarket approach of 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 directly profit from selling rights to develop for the platform. They also have the ability to subsidize developers to encourage application development.

This paper differs from the components versus systems approach in MATUTES & REGIBEAU (1988), CHURCH & GANDAL (1988) and ARORA & BOKHARI (2007) by analyzing atomistic producers of secondary components instead of two (or more) components produced by the same (or different) firms. I place 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. My approach has the advantage of emphasizing cross-group externalities and

[2] See for example CAILLAUD & JULLIEN (2003), ROCHET & TIROLE (2003, 2006), HAGIU (2006), and ARMSTRONG (2006).

[3] One of the results in HAGIU & LEE (2007) is that firms might want to give up control rights over pricing content in order to relax competition. This result is perhaps most closely related to this paper as a firm here might want to give up all gains (from consumers and/or from third-parties) in order to relax competition.

pricing to internalize them. The drawback is that I assume away potentially important strategic interactions between the price of the product and the price of applications set by application developers.

■ The model

I study a two-stage duopoly model of a two-sided market where firms connect consumers with third party application providers. There are two firms, $k \in \{1,2\}$, each with the same intrinsic value v. The value of any applications developed in-house by the firm is also included in v. The number of these applications is exogenous and independent of whether the firm allows for or restricts third party development. For example, the same basic set of applications (such as a calendar, a phone book, an alarm clock, a simple game) bundled with high-end phones open to development are also often available on low-end phones that do not allow development.

The firms can be open to third party development, in which case they are platforms that connect consumers with application developers, or they can be closed to development and simply sell the product of value v to consumers. Firms can also set a fee (or subsidy) for the right to develop an application.

The cost for allowing third party application development is zero. Fixed costs are sunk and marginal costs zero. Consumers only buy one product or platform, but application developers may develop for any or both of the platforms that allow for development.

Consumers

Consumers are uniformly distributed on the unit interval ($x \in [0,1]$) with the firms, $k \in \{1,2\}$, located at the endpoints of the interval. The intrinsic value of the products (or platforms), v, is sufficiently large for the market to be completely covered.

In the eyes of consumers, the firms only differ in price and the number of applications available. A consumer denoted by i receives utility

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

if buying from firm 1 and utility

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

if buying from firm 2. The number of applications available are given by n_{a1} and n_{a2}. The parameter $b > 0$ measures the marginal value to the consumer of a third party application. Prices are p_1 and p_2. The transportation cost parameter, t, measures the intensity of competition between firms. Finally, define by n_{ck} the number of consumers buying from platform k.

Application developers

The application developers are independent monopolists. They are treated as atomistic and are uniformly distributed on the unit interval, $y \in [0,1]$. Developers are heterogeneous in terms of fixed costs for coming up with a business idea, setting up shop and developing an application. An application developer indexed by y_j has fixed costs equal to fy_j for developing an application. Note that to keep the model tractable and symmetric, application developers have no initial favored platform to develop for and they view platforms as symmetric given the same number of consumers using them and the same fee for application development.

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 they both allow for third party application development. Then, application developers make the decision to develop for one platform independently of the decision to develop for the other platform. Thus, there is no direct competition between the firms for developers. A firm can attract more developers by either reducing 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.

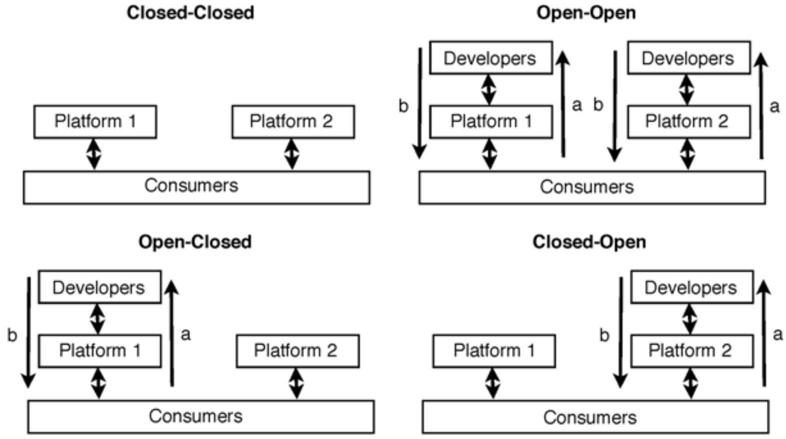
Conditional on the number of consumers at each platform, an application developer j has profits equal to

$$\pi_{jk} = an_{ck} - fy_j - s_k \quad [3]$$

from platform $k \in \{1, 2\}$. The costs of developing applications are sufficiently high to ensure that some developers always stay out of the market.

Parameter s_k denotes 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 reduces the costs of developing an application, such as training, subsidized conferences and free extensive documentation of interfaces.

Figure 1 - Platforms can either be open or closed to third party application development



Timing

In stage 1, firms simultaneously decide whether to be open or closed to third party development. Figure 1 illustrates possible outcomes.

In stage 2, firms observe the choice made by the rival. Then, they simultaneously set prices to consumers. Firms allowing third party application development also set the fee or subsidy to application developers. Consumers and developers then observe prices and the fees or subsidies. They form rational expectations regarding participation of the opposite group. Then, consumers buy the platform yielding the highest utility and developers decide separately for each platform if they should develop for the platform.

This timing captures the fact that the choice of being open or closed to third party application development is more long term than the choice of prices and fees (subsidies). It allows firms to commit to allowing development or not before setting prices and fees. That consumers and application developers make their adoption decisions simultaneously captures the fact that they arrive in a sufficiently alternated fashion. I thus abstract from situations in which one side clearly arrives before the other. The assumption that consumers form rational expectations also implies that adoption dynamics such as solving a chicken-and-egg problem (see e.g. CAILLAUD & JULLIEN, 2003) are set aside.

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 four sub-games outlined in Figure 1. Then, I move back to the first stage of the game and analyze the choice of being open or closed to third party application development.

Analysis

Stage 2: closed-closed

When both platforms are closed to development, the setup reduces to the standard Hotelling model with firms at both endpoints of the unit interval. For the consumer who is indifferent between purchasing from firm 1 or firm 2

$$v - tx_i - p_1 = v - (1 - x_i)t - p_2 \qquad [4]$$

holds. Then, demand for firm 1's product is $n_{c1} = \frac{1}{2} + \frac{p_2 - p_1}{2t}$. Demand for firm 2's product is $n_{c2} = 1 - n_{c1}$. The firms simultaneously set price to maximize $\pi_{kCC} = p_k n_{ck}$ resulting in equilibrium prices of $p^*_{kCC} = t$, and profits of $\pi^*_{kCC} = \frac{t}{2}$.

Stage 2: open-open

The consumer indifferent between purchasing platform 1 and purchasing platform 2 is located at the x_i satisfying

$$v + bn_{a1} - tx_i - p_1 = v + bn_{a2} - (1 - x_i)t - p_2 \quad [5]$$

Demand for firm 1's platform conditional on the number of applications at each platform is then equal to $n_{c1}^{cond} = \frac{1}{2} + \frac{bn_{a1} - bn_{a2}}{2t} + \frac{p_2 - p_1}{2t}$. Demand for firm 2's platform conditional on the number of applications at each platform is $n_{c2}^{cond} = 1 - n_{c1}^{cond}$. The developer who is indifferent between developing and not developing an application for platform k is located at $y_j = \frac{an_{ck} - s_k}{f}$. Demand for developing applications for platform $y_j = \frac{an_{ck} - s_k}{f}$ conditional on the number of consumers purchasing each platform is then $n_{ak}^{cond} = \frac{an_{ck} - s_k}{f}$.

Simultaneously solve equations $n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$, $n_{a1} = n_{a1}^{cond}$ and $n_{a2} = n_{a2}^{cond}$ to obtain demands as functions of prices on both sides of the market:

$$n_{c1}(p_1, p_2, s_1, s_2) = \frac{b(s_2 - a - s_1) + f(p_2 - p_1 + t)}{2(ft - ab)}, \quad [6]$$

$$n_{c2}(p_1, p_2, s_1, s_2) = \frac{b(s_1 - a - s_2) + f(p_1 - p_2 + t)}{2(ft - ab)}, \quad [7]$$

$$n_{a1}(p_1, p_2, s_1, s_2) = \frac{a(b(s_1 + s_2) + f(p_2 - p_1 + t)) - a^2 b - 2fs_1 t}{2f(ft - ab)}, \text{ and} \quad [8]$$

$$n_{a2}(p_1, p_2, s_1, s_2) = \frac{a(b(s_1 + s_2) + f(p_1 - p_2 + t)) - a^2 b - 2fs_2 t}{2f(ft - ab)} \quad [9]$$

Given these demand functions, firms simultaneously set prices, p_k, to consumers and the fees (subsidies) to application developers, s_k, to maximize $\pi_{kOO} = p_k n_{ck} + s_k n_{ak}$.

Equilibrium prices are $p^*_{kOO} = t - a(a+3b)/4f$ and $s^*_{kOO} = (a-b)/4$, and platform profits are $\pi^*_{kOO} = (1/2)t - (a^2 + 6ab + b^2)/16f$. 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 $4ft - (a+b)^2 > 0$. This is a technical condition required for an equilibrium to exist, which can be rewritten as $ft > \left(\frac{a+b}{2}\right)^2 > 0$.

It says that the product of the transportation cost and the fixed entry cost must be larger than the square of the average of the cross-group externalities.

Firms balance the 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 an additional consumer ($b > a$).

As noted by ARMSTRONG (2006), 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 the competition for consumers is intensified when platforms are open to third party application development and network effects are present. A cut in the price leads to more consumers buying the platform. It also attracts more application developers because more consumers have bought the platform. Both platforms then have strong incentives to cut price. These incentives are increasing in the size of 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 network externalities. Since profits are decreasing in the size of the cross-group network externalities, firms would like to reduce them. This gives firms an incentive to restrict third party application development in stage 1 as it removes cross-group externalities.

Stage 2: open-closed and closed-open

Assume that firm 1 has the platform with third party application development and firm 2 has restricted development and only sells a product. The formulas for the reverse case can easily be obtained by renaming the firms.

Conditional on the number of applications developed for platform 1, the consumer who is indifferent between platforms is located at the x_i that satisfies

$$v + bn_{a1} - tx_i - p_1 = v - (1 - x_i)t - p_2 \,. \qquad [10]$$

Demand for firm 1's platform 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 firm 2's product conditional on the number of application developers that develop for platform 1 is $n_{c2}^{cond} = 1 - n_{c1}^{cond}$. The developer who is 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, simultaneously solve equations $n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$ and $n_{a1} = n_{a1}^{cond}$. This gives

$$n_{c1}(p_1, p_2, s_1) = \frac{bs_1 + f(p_1 - p_2 - t)}{ab - 2ft}\,, \qquad [11]$$

$$n_{c2}(p_1, p_2, s_1) = \frac{ab - bs_1 - f(p_1 - p_2 + t)}{ab - 2ft}\,, \text{ and} \qquad [12]$$

$$n_{a1}(p_1, p_2, s_1) = \frac{a(p_1 - p_2 - t) + 2s_1 t}{ab - 2ft}\,. \qquad [13]$$

Firm 1 sets the price to consumers and the fee (or subsidy) to application developers to maximize $\pi_{1OC} = p_1 n_{c1}(p_1, p_2, s_1) + s_1 n_{a1}(p_1, p_2, s_1)$. Firm 2 simultaneously sets the price to consumers to maximize $\pi_{2OC} = p_2 n_{c2}(p_1, p_2, s_1)$. Equilibrium prices are

$$p_1^* = \frac{(4ft - a(a+b))(3ft - ab)}{f(12ft - a^2 - 4ab - b^2)}, \quad [14]$$

$$s_1^* = \frac{(a-b)(3ft - ab)}{12ft - a^2 - 4ab - b^2}, \text{ and} \quad [15]$$

$$p_2^* = \frac{(6ft - (a+b)^2)(2ft - ab)}{f(12ft - a^2 - 4ab - b^2)}. \quad [16]$$

Figure 2 - The simultaneous move game played in stage 1

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

Platform profits are

$$\pi^*_{1OC} = \frac{(8ft - (a+b)^2)(ab - 3ft)^2}{f(a^2 + 4ab + b^2 - 12ft)^2}, \text{ and } \pi^*_{2OC} = \frac{((a+b)^2 - 6ft)^2(2ft - ab)}{f(a^2 + 4ab + b^2 - 12ft)^2}$$

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 instead of Open-Closed. These profits are $\pi^*_{1CO} = \pi^*_{2OC}$ and $\pi^*_{2CO} = \pi^*_{1OC}$. Application developers are subsidized if $b > a$. The size of cross-group network externalities and the costs of developing applications can either increase or decrease profits. The reason is that while cross-group externalities increase the value of the platform to consumers, they also lead to intensified competition for consumers.

Stage 1: Open or Closed to Third Party Application Development?

The firms simultaneously decide if third-parties should be able to develop for their platform. By solving the first stage, illustrated in Figure 2, we can obtain the following proposition.

Proposition 1: For sufficiently large differences in cross-group network externalities, both firms are open to third party application development.

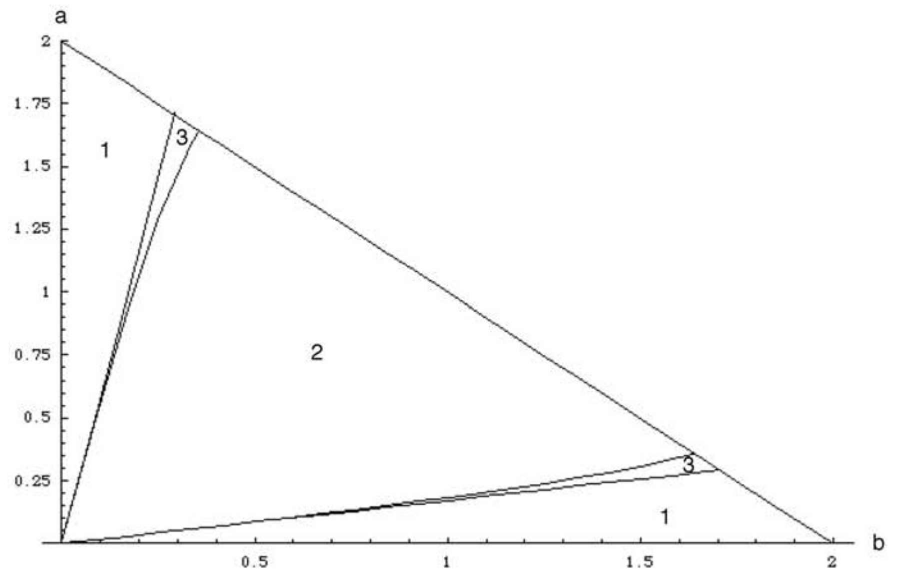
They are trapped in a prisoner's dilemma. If the difference in cross-group network externalities is sufficiently small, both firms restrict third party application development in order to reduce network effects and relax competition. For intermediate differences in cross-group network externalities, one platform is open to third party application development and the other is closed.

To see this, first assume that it is desirable for firm 1 to allow development if firm 2 does not allow development. 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 $(a-b)^2-4ab>0$ (there is a 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 allow for application development. This also holds for firm 2. Hence, the pure strategy Nash equilibrium is for both firms to be open to third party application development. 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 prisoner's dilemma.

Second, now suppose 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 $\pi^*_{1OO} < \pi^*_{1CO}$, the game has two pure strategy Nash equilibria; either firm 1 is open to development and firm 2 is closed or the reverse holds. Equilibria of this type must lie in area 3 in Figure 3, but area 3 also contains parameter combinations resulting in an equilibrium characterized by both platforms allowing third party development.

Third, now assume that it is desirable for firm 1 to restrict application development if firm 2 also does so. Then, $2a^2b^2+(a^2-6ab+b^2)ft<0$ and it is possible to use this to show that $\pi^*_{1CO} > \pi^*_{1OO}$. Firm 1 has a dominant strategy to restrict development. This also holds for firm 2 and the pure strategy Nash equilibrium is for both firms to restrict application development (area 2 in Figure 3).

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 areas 1 and 3 to $(a-b)^2-4ab=0$ and the line separating areas 2 and 3 to the equation $2a^2b^2+(a^2-6ab+b^2)ft=0$. Varying f or t scales the picture. Comparing with Figure 2, Region 1 corresponds to the OO outcome, region 2 to the CC outcome and region 3 to the outcomes OC, CO or OO.

The proposition underscores that firms may have a dominant strategy to restrict third party application development; this takes place despite the fact that allowing development is free and the product increases in value for consumers. The reason is that competition is intensified when there are network effects between consumers and application developers. All else equal, a given price cut to consumers when development is possible attracts more new consumers as compared to when development is restricted because the price is lower and platform value 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 it restricts development are

$$p_1(p_2)_{CC} = \frac{t+p_2}{2}, \text{ and} \qquad [17]$$

$$p_1(p_2, s_2)_{CO} = \frac{t + p_2}{2} - \frac{b(a - s_2)}{2f}. \quad [18]$$

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

$$p_1(s_1, p_2)_{OC} = \frac{t + p_2}{2} - \frac{(a + b)s_1}{2f}, \text{ and} \quad [19]$$

$$p_1(s_1, p_2, s_2)_{OO} = \frac{t + p_2}{2} - \frac{(a + b)s_1}{2f} - \frac{b(a - s_2)}{2f}. \quad [20]$$

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 is open to application development [4]. Hence, by restricting third party application development, firms are able to reduce the intensity of competition for consumers by removing network effects.

In equilibrium, the effect on profits from allowing third party development depends on a balance between benefits from an increase in the value of the platform and the possibility to profit from application developers and intensified competition for consumers [5].

For a sufficiently similar to b, both firms have individual incentives to restrict third party application development. Allowing development 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 third party application developers, the firm finds it profitable to be open to development because

4 Firm 1 is either more or less aggressive in pricing when allowing application development. If $b > a$, so that $s_1 < 0$ 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.

5 There is a difference between a standard quality increase of the platform and a quality increase induced by more application developers developing for the platform. The size of a standard quality increase does not depend on price, whereas the quality increase due to more application developers depends on prices on both sides of the market. Further, the total profits of the platform are the sum of profits from consumers and profits from application developers, so that increases in quality brought about through having more application developers have a different effect on profits than standard quality increases.

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 allow for development. The value 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 prisoner's dilemma. They would have been better off had they been able to collude in stage 1 on restricting application development.

For intermediate differences in a and b, it may be that platforms prefer to allow development if the rival restricts it and to restrict development if the rival allows it. In these cases profit increases from allowing development are enough to compensate for intensified competition only if the rival restricts development. The reason is that competition is more intense when both firms are open to development than if only one firm is open to development. Area 3 in Figure 3 contains such parameter combinations, but area 3 also contains parameter combinations where the equilibrium is for both firms to allow for third party application development.

Finally, application development costs (f) and the intensity of competition between platforms (t) also affect the choice of being open or closed to third party application development. Increased development costs for applications and decreases in the intensity of competition (increases in t) tend to make restricting development more likely due to diminished benefits from cross-group network externalities. This can be seen by noting that if ft is large and the difference in cross-group externalities small, it is more likely that $\pi^*_{1OC} < \pi^*_{1CC}$ and $\pi^*_{1CO} > \pi^*_{1OO}$ since it is more likely that $2a^2b^2 + (a^2 - 6ab + b^2)ft < 0$.

■ Welfare

Can restricting third party application development to relax competition occur when it would be socially desirable that the platforms are open to third party application development? To answer this question we need to determine consumer surplus and application developer profits under each possible outcome in stage 2.

Consumer surplus when both firms restrict application development is $CS^*_{CC} = \int_0^{x^*_{in}} (v - tx - p^*_1)dx + \int_{x^*_{in}}^1 (v - t(1-x) - p^*_2)dx = v - \frac{5t}{4}$. Third party application providers' profits are zero since they cannot interact with consumers. If both platforms allow for application development, consumer surplus and application provider profits are

$$CS^*_{OO} = \int_0^{x^*_i} (v + bn^*_{a1} - tx - p^*_1)dx + \int_{x^*_i}^1 (v + bn^*_{a2} - t(1-x) - p^*_2)dx = v - \frac{5ft - a^2 - 4ab - b^2}{4f} \quad [21]$$

and

$$\Pi^*_{OO} = \int_0^{y^*_{j1}} (an^*_{c1} - fx - s^*_1)dx + \int_0^{y^*_{j2}} (an^*_{c2} - fx - s^*_2)dx = \frac{(a+b)^2}{16f}. \quad [22]$$

Finally, under the asymmetric outcomes when one firm allows for application development and the other restricts development consumer surplus and third party developer profits are

$$CS^*_{OC} = \int_0^{x^*_i} (v + bn^*_{a1OC} - tx - p^*_{1OC})dx + \int_{x^*_i}^1 (v - t(1-x) - p^*_{2OC})dx$$
$$= \frac{2(ab - 3ft)(((a+b)^2 - 5ft)(ab - 3ft) + f(a^2 + 4ab + b^2 - 12ft)v)}{f(a^2 + 4ab + b^2 - 12ft)^2} +$$
$$\frac{((a+b)^2 - 6ft)(((a+b)^2 - 6ft)(2ab - 5ft) + 2f(a^2 + 4ab + b^2 - 12ft)v)}{2f(a^2 + 4ab + b^2 - 12ft)^2} \quad [23]$$

and

$$\Pi^*_{OC} = \int_0^{y^*_{j1}} (an^*_{c1OC} - fy - s^*_{1OC})dy = \frac{(a+b)^2(ab - 3ft)^2}{2f(a^2 + 4ab + b^2 - 12ft)^2}. \quad [24]$$

Given these expressions, which of the four possible combinations of being open or closed to third party development would maximize social welfare? Suppose that social welfare is measured as the sum of consumer surplus, firm profits and third party developer profits. Then, it is best for total welfare to have both firms allow for development if

$$CS^*_{OO} + \pi^*_{1OO} + \pi^*_{2OO} + \Pi^*_{1OO} > CS^*_{CC} + \pi^*_{1CC} + \pi^*_{2CC}, \quad [25]$$

$$CS^*_{OO} + \pi^*_{1OO} + \pi^*_{2OO} + \Pi^*_{1OO} > CS^*_{OC} + \pi^*_{1OC} + \pi^*_{2OC} + \Pi^*_{OC}, \text{ and} \quad [26]$$

$$CS_{OO}^{*} + \pi_{1OO}^{*} + \pi_{2OO}^{*} + \Pi_{1OO}^{*} > CS_{CO}^{*} + \pi_{1CO}^{*} + \pi_{2CO}^{*} + \Pi_{CO}^{*} . \qquad [27]$$

The first condition always holds since the difference between the left-hand and right-hand side is $\frac{1}{f}((a+b)^2) > 0$. The second and third conditions are equivalent in this model. It is possible to show that they hold for ft sufficiently large [6]. Hence, for sufficiently large ft, it is socially optimal that both platforms allow for third party application development.

If the firms privately choose between allowing and restricting third party application development, each firm will have a dominant strategy to provide an open platform if $\pi_{1OC}^{*} > \pi_{1CC}^{*}$, $\pi_{2CO}^{*} > \pi_{2CC}^{*}$, $\pi_{1OO}^{*} > \pi_{1CO}^{*}$, and $\pi_{2OO}^{*} > \pi_{2OC}^{*}$. The first two and the second two conditions are equivalent. The first two conditions hold for $2a^2b^2 + (a^2 - 6ab + b^2)ft > 0$, which is positive for large ft only if $a^2 - 6ab + b^2 > 0$ or, equivalently, if $(a-b)^2 - 4ab > 0$. Hence, for large ft and sufficiently small difference in cross group externalities, so that $(a-b)^2 - 4ab < 0$, firms would not have any incentives to allow for third party application development even if it were socially desirable.

Proposition 2: There exist cases where competing platforms restrict third party application development in a sub-game perfect equilibrium when total welfare would be higher if the firms allowed for third party application development.

The reason for why firms do not have incentives to be open to third party application development is that it makes the rival more aggressive in pricing. Proposition 2 then suggests that there may be situations in which a policy of supporting open platforms is warranted; particularly when firms seem to restrict third party application development in order to reduce competition for consumers.

[6] The difference between the left-hand and right-hand side can be simplified to $4(17a^4 + 72a^3b + 106a^2b^2 + 72ab^3 + 17b^4)ft < 3(a+b)^2(a^4 + 8a^3b + 10a^2b^2 + 8ab^3 + b^4 + 72f^2t^2)$ which holds for sufficiently large ft.

Discussion on extensions

This stylized model can be extended in several directions. First, it was assumed that the market was completely covered on the consumer side. This implies that price cuts to consumers by the firms do not attract new customers; neither do increases in quality from allowing third party application development. Maintaining the assumption of a covered market thus biases the results in favor of restricting application development. The assumption does not, however, change the fact that competition between firms with third party applications is more intense than competition between firms that does not have third party applications.

Second, the current setup does not allow the firms to choose between in-house application development and outsourcing the development of applications to third-parties. I only consider the choice between allowing third party application development or not. This is likely to bias the results in favor of allowing third party development as this is the only way to increase the quality of the product sold.

Third, it was assumed that there is no cost to the platform for allowing third party application development. Introducing a fixed cost for developing the capabilities for third party producers to develop applications is not likely to change the nature of the results other than increasing the benefit to platforms from restricting third party application development. It may also be that unauthorized third party application development takes place. In that case, opening the platform to third party application development may involve cost savings, as costly measures to restrict unauthorized use and development of applications no longer need to be undertaken. In this case the results would change so that it would be more likely for the platforms to be open to third party application development.

Fourth, it was assumed that third party application developers had to incur the fixed cost of developing an application once for each platform. Once an application has been developed, however, it is likely that porting it to another platform is less expensive than rewriting it completely. Introducing this aspect into the model potentially significantly complicates the analysis. The reason is that in the current set up, each application developer decides on developing for one platform independently of the decision to develop for the other. As a consequence, the firms only compete directly for users and not for application developers, as the choice to develop for one is independent of the choice to develop for the other. If the costs for developing an application are conditional on whether the application has previously been developed, development choice becomes interdependent. The likely bias of this extension on the results is not clear and hence, is a good direction for future research. Existing complementary work on the issue of porting in two-sided markets include POLLOCK (2008).

■ Concluding remarks

Why are some platforms open to third party application development while others are closed? In this paper, I take a two-sided market approach and highlight that being open to third party development intensifies competition for consumers. Hence, firms might prefer to commit to restricting development despite the fact that applications are valuable to consumers and allowing third party application development is free.

In a two-stage model of a two-sided market, I find three types of equilibrium configurations: both firms allow development (and the firms are trapped in a prisoner's dilemma); both firms restrict development; or one firm allows development and the other restricts it. The outcome depends on the relative difference in cross-group externalities, the intensity of competition for consumers and the cost for developing applications.

The policy implications are that competing platforms may have incentives to restrict third party application development even when it is desirable for society that they are open to development. In particular, the model suggests that private and social incentives to open the platforms diverge when consumer transportation costs and application developer fixed costs are large, and when there is a small difference in cross group externalities so that it is not clear which side values the other more. Under these conditions - and if firms provide closed platforms - a policy in support of open platforms could be beneficial to society.

As regards to future research, the model is cast in the framework of software and hardware platforms. It could also apply to other two-sided markets where choosing between providing a one-sided product or a two-sided platform is possible. In particular, as a firm can be open or closed to advertisers, the analysis could be adapted to study how magazines and TV stations are funded along the lines of KIND, NILSSEN & SORGARD (2005).

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