View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by DSpace@MIT

MIT Sloan School of Management

MIT Sloan School Working Paper 4684-08
12/31/2007

Innovation, Openness, and Platform Control

Geoffrey Parker, Marshall Van Alstyne

© 2007 Geoffrey Parker, Marshall Van Alstyne

All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission, provided that full credit including © notice is given to the source.

This paper also can be downloaded without charge from the
Social Science Research Network Electronic Paper Collection:
http://ssrn.com/abstract=1079712

Innovation, Openness, and Platform Control

Geoffrey Parker
Tulane University
gparker@tulane.edu

Marshall Van Alstyne
Boston University/MIT
mva@bu.edu

31-December-2007

Abstract: We explore innovation, openness, and the duration of intellectual property protection in markets characterized by platforms and their ecosystems of complementary applications. We find that competition among application developers can reduce innovation while competition among platforms can increase innovation. Developers can be better off submitting to platform control as opposed to producing for an unsponsored platform. Although a social planner would open a platform sooner and to a greater degree than would a private platform sponsor, a platform sponsor's ability to control downstream innovation gives it reason to behave more like a social planner. However, if platforms are to perform this role, platform sponsors need longer duration rights than application developers. Results can inform antitrust and intellectual property regulation, technological innovation, competition policy, and intellectual property strategy.

Keywords: Sequential Innovation, Platform Economics, IT Systems Design, Copyright and Patent Length, Network Effects, Network Externalities

Acknowledgments: This work has been supported by National Science Foundation Grants IIS-0338662 and SES-0323227 as well as grants from Cisco Systems Inc. and the Microsoft Corporation.

1 Introduction

Platform business models have become a ubiquitous feature of the information economy. Common products such as personal computers, cell phones, gaming systems, streaming media, and telecommunications infrastructure can be described in terms of systems where developers build "applications" on top of a "platform." As a result of the increasing economic importance of platforms, a growing literature has worked to define platform design (e.g., Cusumano & Gawer 2002), platform economics, and the associated business strategies for managing them (see, e.g., Boudreau, 2007; Bresnehan & Greenstein, 1999; Farrell, Monroe, & Saloner, 1998).

Recent literature conceives of platforms as mediating markets with two-sided network externalities and analyzes pricing across potentially distinct user groups (for early works on this topic, see Caillaud & Jullien, 2003; Parker & Van Alstyne, 2005; Rochet & Tirole, 2003). To date, however, there has been little formal modeling to address the question of how a platform sponsor can exercise non-price control in order to capture profits and promote overall platform growth. Earlier work explored the related issue of how to foster sequential innovation through patent length and breadth at the regulatory level, leaving open the question of how firms themselves could use these results (e.g., Chang, 1995; Gilbert & Shapiro, 1990; Green & Scotchmer, 1995; Klemperer, 1990; Landes & Posner, 2003).

Our analysis is closer in spirit to Bessen and Maskin (forthcoming) who develop a model of complementary sequential innovation to show that delays in copying can provide firms with sufficient incentives to innovate even in the absence of patent or copyright protection. Our analysis of developer competition parallels Rey and Salant (2007) who analyze the effect of licensing on downstream innovation. We build on the sequential innovation literature and broaden the analysis to the following set of questions: When should a platform sponsor open a resource to outside development? How does competition affect openness? How does the ability to reuse platform assets affect the level of openness? Does the number of downstream developers or their added value affect openness? If downstream developers do add value, should the firm privately subcontract with a subset or should the firm open the platform to the entire developer pool? When should a platform fold new developer applications into the platform?

To address these questions, we develop a tractable model of downstream production by developers who add value to a platform by producing applications. We conceive of a platform as the components used in common across a product family (Boudreau, 2007) whose functionality can be extended by applications. Our model accounts for the ability to reuse output from one period as production input in the next period. Developers can then incorporate platform assets into their applications development. Further, the development of second generation applications can depend on the value and quantity of applications developed in the first. The tradeoff is that converting assets from closed to open sacrifices salable assets, thus creating a tension between current profit and future growth. The model allows us to demonstrate (i) the optimal level of openness for a platform (ii) when downstream applications should also become open in order to promote second generation application production, (iii) when a platform sponsor should use closed subcontracts instead of decentralized open innovation, (iv) how competition affects openness, and (v) why the presence of a platform sponsor that forces openness on downstream developers can make even developers themselves (as well as users) better off. The regulatory implication is that sponsors need longer term property rights than developers in order to effectively manage downstream innovation. Section 2 develops the model and main results. Section 3 considers extensions to the core model. We conclude in Section 4.

2 The Model

We consider three points of value in a platform ecosystem. The first, denoted as V, is the value of the platform independent of developer applications and add-ons. The second and third are the value created by developer production in periods 1 and 2, denoted as y_1 and y_2. We follow Chang (1995) in assuming that consumers share a common value v for each unit y of application produced. Developer output is modeled using a standard Cobb-Douglas production function where k is a reuse coefficient that determines the level of conversion between a stock of open resource, Ω, into applications and add-ons. A technology parameter, α, determines the efficiency of production so $y_i = k\Omega_i^\alpha$. Period one stock $\Omega_1 = \sigma V$ is provided by the platform sponsor by opening up a fraction σ of the platform value, making it freely available to all developers. We assume that leakage to consumers results in a net loss of platform profit. Technological obsolescence prevents developers from reusing open resources more than once (further reuse would only increase the value of openness). Thus, second period open stock, which developers use as input, is the period 1 production and $\Omega_2 = y_1 = k(\sigma V)^\alpha$. Developer output in periods 1 and 2 can be expressed as $y_1 = k(\sigma V)^\alpha$ and $y_2 = k^{1+\alpha}(\sigma V)^{\alpha^2}$. We extend the model in Section 2.2 to consider a direct licensing contract to avoid the loss of platform value. Second period revenue is discounted at rate r.

Let t be the length of the exclusionary period offered to developers during which they can sell their applications at positive profits. That is, analogous to a period of patent protection, t represents the time before which a sponsor agrees not to compete with the developer but after which the sponsor will fold new developer features into the open platform. Newly open features from one developer then become available to all. To facilitate analysis, we combine parameters r and t into discount coefficient $\delta = e^{-rt}$. Time is bounded by $0 \leq t < \infty$ which restricts δ to the range $0 < \delta \leq 1$. Price is then determined by the length of time before an application is forced into the open domain. Consumers know that applications will be freely available after the exclusionary period t. Therefore, developers can charge consumers only for the difference between the full value of the product today and the discounted value of the product when it becomes open and free. Thus, $p = v - \delta v = v(1-\delta)$. If the platform never enveloped new developer applications ($t \to \infty$) then $\delta \to 0$ and $p = v$. Likewise, if the exclusionary period ends immediately ($t = 0$), then $\delta = 1$ and $p = 0$.

We make the same assumption as in Green and Scotchmer (1995) that Nash bargaining governs the revenue split on downstream innovation, giving each party $\frac{1}{2}$ the downstream developer-produced surplus. We assume zero marginal production costs and a sufficiently large value added, V and v, to cover platform and developer fixed costs. For many information goods and even physical goods such as semiconductors, zero marginal cost is a reasonable approximation. Regardless, we consider costs in section 2.2. Developer profit and platform sponsor profits can then be written as

$$\pi_d = \frac{1}{2}py_1 + \delta\frac{1}{2}py_2 \tag{1}$$

$$\pi_p = V(1-\sigma) + \frac{1}{2}py_1 + \delta\frac{1}{2}py_2 \tag{2}$$

Expressing platform sponsor profit in terms of model primitives yields:

$$\pi_p = V(1-\sigma) + \frac{1}{2}v(1-\delta)k(\sigma V)^{\alpha} + \delta\frac{1}{2}v(1-\delta)k^{1+\alpha}(\sigma V)^{\alpha^2} \tag{3}$$

2.1 Platform Sponsor Choice of σ and δ

We now explore the central tension facing the platform sponsor: the degree to which it should sacrifice direct platform profits in order to stimulate downstream innovation, and its commitment to avoid competing directly with developers before expiration of the proprietary period. The optimal contract is a pair $\langle\sigma,\delta\rangle$ (isomorphic to $\langle\sigma,t\rangle$) where choice parameters σ and δ represent the share of value (level of openness) used to subsidize developers, and the period of proprietary developer protection. The amount of production in each period, y_1 and y_2, the discount rate r, and the responsiveness of production to openness will govern a platform sponsor's choices. We assume a convex region of interest, defined by a negative semidefinite matrix with respect to openness and time. We develop conditions for optimal openness in terms of elasticities. The elasticity of output in each period with respect to σ is $\eta_i = \frac{\partial y_i}{\partial\sigma}\frac{\sigma}{y_i}$, $i = 1, 2$.

Proposition 1 *The platform sponsor's optimal choice $\sigma^\star$ is defined by the ratio of production revenues gained to subsidy revenues lost weighted by the elasticity of output per period.*

$$\frac{(1/2)\,p\,y_1}{\sigma V}\eta_1 + \frac{(1/2)\,\delta\,p\,y_2}{\sigma V}\eta_2 = 1 \tag{4}$$

Proof. *To establish the result, first calculate the first-order condition on platform profit with respect to σ:*

$$\frac{\partial \pi_p}{\partial \sigma} = -V + \alpha \frac{1}{2} pk\sigma^{\alpha-1}V^{\alpha} + \alpha^2 \frac{1}{2}\delta pk^{1+\alpha}\sigma^{\alpha^2-1}V^{\alpha^2} = 0. \tag{5}$$

Add V to both sides and premultiply all terms by σ to restore the expressions for output y_1 and y_2. Divide through by σV. Cobb-Douglas models yield, $\eta_1 = \alpha$ and $\eta_2 = \alpha^2$. Substituting η terms for α terms provides the required result. ■

Intuitively, when the platform sponsor opens its core resources to outside parties, the gain from sharing in developer profits must offset platform losses (forgone revenue σV). Opening the platform and subsidizing developers stimulates downstream production. The responsiveness of output to openness is captured in the elasticity terms so that the optimal level of openness properly balances the revenues lost and gained.

We now explore the platform sponsor's choice of time during which developers enjoy proprietary protection for their innovations.

Proposition 2 *The optimal choice $\delta^\star$ is governed by the ratio of developer production in periods 1 and 2.*

$$\delta^\star = \frac{1}{2}\left(1 - \frac{y_1}{y_2}\right) \tag{6}$$

This implies that the condition for a finite duration to protection of platform applications is higher second period output. A further implication is that it is never profit maximizing to force the immediate free release of developer applications.

Proof. *To establish the result for δ, calculate the first-order condition on platform profit with respect to δ. Since δ terms do not appear in output, we express profit in terms of y_1 and y_2.*

$$\frac{\partial \pi_p}{\partial \delta} = -y_1 v + y_2 v(1-\delta) - \delta y_2 v = 0, \tag{7}$$

Rearranging terms provides the required result. ■

Expressing the requirement for finite copyright duration, $y_2/y_1 > 1$ in terms of model primitives produces $\frac{k^{1+\alpha}\sigma^{\alpha^2}V^{\alpha^2}}{k\sigma^{\alpha}V^{\alpha}} > 1$. Raising both sides to $1/\alpha$, this reduces to $\frac{k}{\sigma^{1-\alpha}V^{1-\alpha}} > 1$. Clearly, a larger reuse coefficient, k, makes the existence of a second period more likely, while a larger platform value V makes a finite time less likely. A further re-arrangement of this condition is that $y_1 > \sigma V$ which implies that there is never a second period unless the first period developer production exceeds the amount of the platform that is given away.

In Corollary 1 below, we explore the effect of model primitives on the platform sponsor's choice variables. Time moves in the opposite direction from the discount coefficient δ. We provide detailed derivations in the Appendix.

Corollary 1 *Comparative Statics – The following table summarizes effects of model primitives on platform sponsor choices of optimal contract.*

	$\sigma^\star$	$\delta^\star$	$t^\star$
Platform value: V	-	-	+
Developer value: v	+	-	+
Reuse coefficient: k	+	+	-
Technology: α	*indeterminate*	*indeterminate*	*indeterminate*

(8)

Proof. *To produce sensitivity analyses, we employ the envelope theorem to determine the sign of each effect. Derivations appear in the Appendix.* ■

Rising platform value V implies closing the platform more and folding in new features later. Equation 4 shows this directly for $\sigma^\star$ since V only appears as part of σV. A more valuable initial platform means that less of its value can be sacrificed to stimulate developer production. Interestingly, rising platform value also lengthens $t^\star$ the proprietary period offered to developers. In effect, larger V implies the sponsor prefers to take profits directly instead of relying on indirect downstream innovation.

In contrast, increasing the developer value, v, per unit produced has the effect of increasing the sponsor's willingness to open the platform. The sponsor rationally sacrifices direct platform profits in order to share in rising developer surplus. Somewhat surprisingly, an increase in the value of developer production leads a platform sponsor to offer developers a longer proprietary period $t^\star$. Increased surplus in both periods has the effect of making the sponsor more patient. More valuable new features are folded into the platform later.

As the reuse coefficient, k, rises, developer production increases. This implies opening the platform more but, in contrast, implies folding new features into the platform sooner. The sponsor should sacrifice direct platform profits in order to stimulate indirect developer surplus. In this case, however, reuse is sufficiently important to subsequent second period innovation that the platform sponsor reduces the proprietary period in order to pull second round profits closer in time.

Finally, the technology coefficient, α, has a non-monotonic effect on the platform sponsor's optimal contract. Specific parameter values govern the choice of contract and can cause both openness and time to both rise and fall.

2.2 Welfare

We now extend the model to include fixed costs F and increasing marginal costs cy^2. We continue to assume a convex region of interest, defined by a negative semidefinite matrix with respect to openness and time. These additions allow us to compare the social planner's choices with those of a platform sponsor. In the absence of costs, welfare analysis becomes uninteresting. The social planner simply allocates all existing resources for innovation without delay and chooses $\langle \sigma_w^*, t_w^* \rangle = \langle 0, 1 \rangle$.

A positive price, $v(1-\delta) > 0$, represents a wealth transfer from consumers, while the platform subsidy σV represents a wealth transfer from the platform sponsor. Both are irrelevant to a social planner except to the degree that developers must cover development costs. The following welfare equation then determines the social planner's optimization.

$$\underset{\sigma_w, \delta_w}{\arg\max} \qquad V + (vy_1 - cy_1^2) + \delta(vy_1 - cy_1^2) - F \tag{9}$$

$$\textit{such that } (py_1 - cy_1^2) + \delta(py_1 - cy_1^2) \geq F \tag{10}$$

Adding analogous fixed and marginal costs to platform sponsor profit, Equation 2, provides the basis for comparison.

Proposition 3 *The social optimum is a contract $\langle \sigma_w^*, \delta_w^* \rangle$ with $\sigma_w^* > \sigma^*$ and $\delta_w^* > \delta^*$. The social planner prefers a more open platform and a shorter proprietary period ($t_w^* < t^*$) for applications than do platform sponsors.*

Proof. *We use the Lagrangian to solve for δ_w^* and sort the relative σ_w^*. Under the constrained optimization, cost recovery binds at $v(1-\delta)y_1 + \delta v(1-\delta)y_2 \geq C$ with total costs C defined as $F + cy_1^2 + cy_2^2$. The resulting expression for δ is quadratic. Eliminate the negative root by choosing $c = F = 0$. As expected, the absence of costs implies the positive root becomes $\delta = 1$ and $t = 0$ in the equation below. Compared to δ^* from Proposition 2, the social planner's discount exceeds that of the platform sponsor (the time to envelope applications is shorter) by the following amount.*

$$\delta_w^* = \frac{1}{2}\left(1 - \frac{y_1}{y_2} + \sqrt{\frac{(y_1+y_2)^2}{y_2^2} - \frac{4C}{vy_2}}\right) \tag{11}$$

$$= \delta^* + \frac{1}{2}\left(\sqrt{\frac{(y_1+y_2)^2}{y_2^2} - \frac{4C}{vy_2}}\right) \tag{12}$$

Applying the steps used in Proposition 1 to the system of equations including costs yields the following pair of implicit functions.

$$\sigma_w \;:\; \alpha(vy_1 - 2cy_1^2) + \delta_w \alpha^2 (vy_2 - 2cy_2^2) = 0 \tag{13}$$

$$\sigma \;:\; \alpha(py_1 - 2cy_1^2) + \delta \alpha^2 (py_2 - 2cy_2^2) = 2\sigma V \tag{14}$$

Transform the first by mapping δ_w to δ and the second by mapping price to v. As second period surplus is always non-negative, the welfare and profit constraints are easily sorted.

$$\sigma_w \;:\; \alpha(vy_1 - 2cy_1^2) + \delta\alpha^2(vy_2 - 2cy_2^2) = -\kappa_1 < 0 \qquad (15)$$
$$\sigma \;:\; \alpha(vy_1 - 2cy_1^2) + \delta\alpha^2(vy_2 - 2cy_2^2) = \kappa_2 > 0 \qquad (16)$$

Where $\kappa_1 = \frac{1}{2}\left(\sqrt{\frac{(y_1+y_2)^2}{y_2^2} - \frac{4C}{vy_2}}\right)(\alpha^2(vy_2 - 2cy_2^2)) > 0$ *and* $\kappa_2 = 2\sigma V + \alpha\delta y_1 + \alpha^2\delta^2 y_2 > 0$. *Thus the first constraint binds always to the left of the second. In this case, producing* $\sigma_w^* > \sigma^*$.

■

We observe that the greater the share of downstream innovation captured by the platform sponsor, the greater is the incentive to open. For share $s \in [0,1]$, the platform sponsor's constraint moves with κ_2 as $\frac{1}{s}\sigma V + \alpha\delta y_1 + \alpha^2\delta^2 y_2 > 0$, which falls weakly toward the constraint of the social planner as s rises. This parallels results elsewhere in the literature – internalizing downstream innovation causes the owner of an upstream innovation to behave more like a social planner.

Interestingly, this also shows that higher costs cause the social planner to behave more like the proprietary sponsor. As total costs C rise, the discount of the social planner increasingly resembles that of the platform sponsor.

2.2.1 Developer Number and Competition

To this point, the model has effectively assumed a single developer. How does increasing the size of the developer pool and introducing developer competition affect platform sponsor choices for $\sigma^\star$ and $t^\star$? Increasing the number of developers $N > 1$ raises output in each period such that $\tilde{y_1} = Ny_1$ and $\tilde{y_2} = Ny_2(Ny_1)$. Increasing the intensity of developer competition softens prices such that $\tilde{p} = \gamma p$ with $0 \leq \gamma < 1$. More developers and more intense competition then have the following effects.

Corollary 2 *Increasing the size of the developer pool increases $\sigma^\star$ but decreases $t^\star$. Increasing competitive intensity decreases both $\sigma^\star$ and $t^\star$.*

Proof. *The comparative statics results from Corollary 1 provide a straightforward demonstration. Let $\tilde{k} = Nk$ and $\tilde{v} = \gamma v$ being careful to interpret rising competition as reducing γ.* ■

Intuitively, increasing the number of independent developers increases platform openness because downstream innovation increases at a higher rate. On margin, openness becomes more profitable. Having more developers also decreases the amount of time that applications should remain closed. By folding applications into the platform sooner, the platform sponsor provides more resources to more developers who reuse these innovations as input to subsequent production. Platform envelopment has become marginally more profitable.

More intense competition has different implications. Holding other factors constant, greater developer competition reduces the Nash bargaining surplus available to the platform sponsor. This surplus goes instead to platform users, reducing the sponsor's incentive to open the platform. Ironically, this also has the effect of reducing contributed developer value which reduces the value of keeping applications private, and selling them, as distinct from folding them into the platform. Competition therefore leads the sponsor to reduce the proprietary period.

2.2.2 Platform Competition

We now examine the effect of competition between platforms on the platform sponsor's optimal choice of $\sigma^\star$ and $t^\star$. In the same way that competition reduces developer pricing power, platform competition reduces direct platform price from $(1-\sigma)\,V$ to $(1-\sigma)\,\lambda\,V$ with $0 \leq \lambda < 1$. By varying λ, we see that increasing the intensity of platform competition has the opposite effect of increasing the intensity of developer competition.

Corollary 3 *Increasing the intensity of platform competition increases both* $\sigma^\star$ *and* $t^\star$ *.*

Proof. *To establish the first claim, substitute model primitives for output terms into equation 4 from Proposition 1 and hold all else constant to show that the following equality holds.*

$$\frac{c_1}{\sigma^{1-\alpha}\lambda} + \frac{c_2}{\sigma^{1-\alpha^2}\lambda} \quad = \quad 1 \tag{17}$$

Increasing competitive intensity by decreasing lambda implies increasing σ *in order to maintain the equality. To establish the second claim substitute constants for model parameters other than* σ *into equation 6 from Proposition 2. The optimal choice of* $\delta^\star$ *is governed by the following ratio.*

$$\delta^\star \quad = \quad \frac{1}{2}\left(1 - c\frac{\sigma^\alpha}{\sigma^{\alpha^2}}\right) \tag{18}$$

Given $0 < \alpha < 1$*, we conclude that a larger* $\sigma^\star$ *corresponds to a lower* $\delta^\star$ *which implies a higher* $t^\star$ *.* ∎

Holding all else constant, greater platform competition reduces the direct platform surplus available to the platform sponsor. The sponsor's incentive is therefore to open the platform in order to increase indirect profits from downstream innovation. Because the platform sponsor must take more of its profits from developer revenues, the platform sponsor also has a greater interest in maintaining developer price, which leads the sponsor to increase the proprietary period. The effect of platform competition is therefore to increase both openness and subsequent developer output. In terms of competition policy, the regulatory implication is that to achieve higher innovation, promote developer entry but not developer competition. Instead, promote platform competition which motivates sponsors to open and seek growth. We examine how this interacts with private subcontracting and property rights next.

2.3 User Participation and Implications for Subcontracting

Up to this point, we have assumed that firms rationally open their platforms to seek innovation. The cost of openness, however, is that the sponsor sacrifices profits on assets he could otherwise sell. Firms can avoid this cost by subcontracting directly with developers. Keeping the platform closed converts direct platform profits to $V(1-\sigma)\mid_{\sigma=0}= V$ Further, direct negotiation has the added benefit that the sponsor can share access to the full technology embedded within the platform, sharing only with subcontractors and no one else. This parallels Apple's strategy of sharing with a small developer pool and producing a tightly integrated system (Boudreau 2007). Sharing only privately with subcontractors and giving them full access increases their output to $y_1 = \frac{1}{2}pk(\sigma V)^{\alpha}\mid_{\sigma=1}$ and $y_2 = \frac{1}{2}\delta pk^{1+\alpha}(\sigma V)^{\alpha^2}\mid_{\sigma=1}$. With these two benefits, modified platform profits become:

$$\pi_{sub} \quad = \quad V + \frac{1}{2}pkV^{\alpha} + \frac{1}{2}\delta pk^{1+\alpha}V^{\alpha^2}$$

In contrast, the virtue of openness is broader participation and increased user value. Mechanisms by which openness might increase willingness to pay or platform participation include ability of users to modify open systems, transparency and lack of "spyware," free redistribution, openness as a commitment to low price analogous to second sourcing (Farrell & Gallini, 1988), and lack of negotiation costs. This last attribute is especially salient for developers of novel applications who risk disclosing their ideas by identifying themselves or their applications to the platform sponsor (Bessen & Maskin, forthcoming). Recent work on "two-sided" networks (Rochet & Tirole, 2003; Parker & Van Alstyne, 2005) also demonstrates how subsidizing a developer community, as with σV, increases platform value to and participation of a user community. Reciprocally, broadening the user base attracts a larger developer base. For a variety of reasons, openness can increase both value and participation.

The question we address in this section is when the benefits of openness outweigh the benefits of subcontracting. With minor modifications, we can analyze when openness modifies intrinsic application value $\tilde{v} = Mv$ and when it modifies developer participation such that output moves with $\tilde{y} = My$. Respectively, these two changes modify sponsor payoffs as follows:

$$\begin{aligned}\pi_{open\ value} &= V(1-\sigma) + \frac{1}{2}Mpy_1 + \frac{1}{2}\delta Mpy_2(y_1)\\ \pi_{open\ output} &= V(1-\sigma) + \frac{1}{2}pMy_1 + \frac{1}{2}\delta pMy_2(My_1)\end{aligned}$$

The result is that increased willingness-to-pay and increased participation can each justify an open platform relative to closed subcontracting. The latter has a larger effect due to the compounding effects of production. More formally, we provide a strong bound.

Proposition 4 *If the platform sponsor values second period production, an open platform is more profitable than a closed subcontract whenever the multiplier on value is* $M > \frac{1}{\sigma^{\alpha^2}} + \frac{\sigma V}{\delta p y_2}$*. Measured in terms of participation, this multiplier falls to* $M > (\frac{1}{\sigma^{\alpha^2}} + \frac{\sigma V}{\delta p y_2})^{\frac{1}{1+\alpha}}$.

Proof. *The platform sponsor prefers openness when* $\pi_{openvalue} > \pi_{sub}$ *or, after subtracting and grouping terms, when* $\sigma V < \frac{1}{2}pkV^{\alpha}(1 - M\sigma^{\alpha}) + \frac{1}{2}\delta pk^{1+\alpha}V^{\alpha^2}(1 - M\sigma^{\alpha^2})$*. When the sponsor values second period production, the second righthand term exceeds the first. Thus a stronger bound on the inequality is* $\sigma V < 2\frac{1}{2}\delta pk^{1+\alpha}V^{\alpha^2}(1 - M\sigma^{\alpha^2})$*. Algebraic simplification yields* $\frac{\sigma V}{\delta pk^{1+\alpha}V^{\alpha^2}} < M\sigma^{\alpha^2}$*. Division, then substituting for the definition of* y_2 *provides the necessary expression. An identical sequence of steps for* $\pi_{openoutput} > \pi_{sub}$ *that accounts for the compound effect of technology produces the second expression.* ■

Opening the platform becomes more attractive (i) as the subsidy σV falls (ii) second round output y_2 grows, and (iii) technology α improves. This proposition argues for decentralized innovation when user-developer network effects rise far enough. Note that the decentralized innovation is achieved without bargaining costs. A default open contract with $\sigma > 0$ gives developers an option to enter the market for any fixed costs up to the amount they can recover, and without current period disclosure to the platform author. They need not risk disclosing their idea to the monopsonistic platform author who could potentially appropriate its value.

2.4 Developer Choice in the Absence of Platform Control

The ability to reuse material from one application in the development of another raises the prospect that developers can reciprocally contribute to one another's forward development. After all, access to a richer pool of application resources fosters richer application development. In effect, the platform sponsor appropriates developer resources at time $t^\star$ in order to make them available to other developers via the platform. Is "confiscation" necessary?

Strategy	T_1 Own		T_2 Other		T_2 Own		T_1 Tail		T_2 Tail
$\pi_{d_i}^{CC} =$	$\frac{1}{2}v(1-\delta)y_1$	$+$	$\frac{1}{2}v\delta^2 N^\alpha y_2$	$+$	$\frac{1}{2}\delta v(1-\delta)y_2$	$+$	0	$+$	0
$\pi_{d_i}^{DC} =$	$\frac{1}{2}v(1-\delta)y_1$	$+$	$\frac{1}{2}v\delta^2 N^\alpha y_2$	$+$	$\frac{1}{2}\delta v(1-\delta)y_2$	$+$	$\frac{1}{2}v\delta y_1$	$+$	$\frac{1}{2}v\delta^2 y_2$
$\pi_{d_i}^{CD} =$	$\frac{1}{2}v(1-\delta)y_1$	$+$	0	$+$	$\frac{1}{2}\delta v(1-\delta)y_2$	$+$	0	$+$	0
$\pi_{d_i}^{DD} =$	$\frac{1}{2}v(1-\delta)y_1$	$+$	0	$+$	$\frac{1}{2}\delta v(1-\delta)y_2$	$+$	$\frac{1}{2}v\delta y_1$	$+$	$\frac{1}{2}v\delta^2 y_2$

Table 1: Surplus from the four strategies available to developers.

To analyze this problem, we consider the outcomes from cooperation versus defection with the former interpreted as contributing to the common resource pool and the latter means withholding resources in order to charge for them. The four strategies we consider are (i) cooperate, cooperate (CC) where the first position denotes the strategy of an individual developer and the second position denotes the action of the remaining developers, (ii) defect, cooperate (DC), (iii) cooperate, defect (CD), and (iv) defect, defect (DD). Denote $\pi_{d_i}^{CC}$ as the profit that an individual developer makes when it cooperates and all other developers cooperate. The profits from the remaining three strategies are denoted similarly.

Individual developer profits differ in two ways. First, individual developers explicitly consider the number N of other applications apart from their own. Second, uncooperative developers can recover the revenues in the tail of the distribution $t > t^\star$. These changes yield the four strategies with surpluses as given in Table 1 and the proposition below.

Proposition 5 *Among developers, [Defect, Defect] constitutes a dominant pure strategy Nash equilibrium.*

Proof. *We show a prisoners' dilemma as follows. Direct comparison of CC and DC profits reveals that a profit-motivated developer prefers to defect when the other developers cooperate. That is $\pi_{d_i}^{DC} = \pi_{d_i}^{CC} + \frac{1}{2}\delta v y_1 + \frac{1}{2}\delta^2 v y_2$. The comparison of $\pi_{d_i}^{DD}$ to $\pi_{d_i}^{CD}$ is similar, showing that profit-motivated developers defect.* ■

Having established that profit-motivated developers will not, in the absence of enforcement, cooperate by freely releasing their enhancements, we ask when a developer would prefer to submit to a contract that would enforce the cooperative CC outcome. That is, we compare the profits under DD to CC. First, note that in the case of DD, there is no open stock release, so the user base and first and second period resource pools remain constant. The only difference is that the developer has access to his own private stock as well as Ω_1.

Proposition 6 *If the platform sponsor chooses $t^\star < \infty$ there exists a contract committing developers to give up their applications that makes them better off whenever $N > 2^{\frac{1}{\alpha}}$.*

Proof. *Comparing differential gains from* $\pi_{d_i}^{CC}$ *to those in* $\pi_{d_i}^{CC}$*, developer profits are higher when* $\frac{1}{2}v\delta^2 k^{1+\alpha}N^{\alpha}(\sigma V)^{\alpha^2} > \frac{1}{2}v\delta k(\sigma V)^{\alpha}+\frac{1}{2}v\delta^2 k^{1+\alpha}(\sigma V)^{\alpha^2}$*. Since* $t^{\star} < \infty$ *it follows that* $y_2 > y_1$ *so* $\frac{1}{2}v\delta^2 k^{1+\alpha}N^{\alpha}(\sigma V)^{\alpha^2} > 2\frac{1}{2}v\delta^2 k^{1+\alpha}(\sigma V)^{\alpha^2}$*. Rearranging produces an expression* $N^{\alpha} > \frac{2\delta}{1-\delta}$ *whose right hand side rises strictly in* δ*. As* δ *reaches its maximum at* $\frac{1}{2}$*, further manipulation produces the required result.* ■

This proposition establishes that the total number of developers only needs to exceed a small constant in order for the cooperative solution to produce greater surplus than the uncooperative solution. This has strong implications for the role of the platform sponsor. Essentially, the sponsor enforces a set of $O(N)$ bilateral contracts binding developers to give up their applications after a reasonable profit period in order that all developers may reuse each others' valuable resources. This not only economizes on $O(N^2)$ transaction costs, it increases the total surplus available to each individual developer.

A consequence of Proposition 6 is that developers can prefer governance by a platform sponsor to that of an uncoordinated open standard. In the absence of orchestrated governance, individual incentives to profit maximize lead to Pareto inferior welfare in terms of innovation and profits. As the comparative statics of Corollary 1 show, the optimal timing of property rights can also depend on industry specific factors such as k and v. If this is true, then an industry platform sponsor can craft more specific timing than a regulator whose rules apply across platforms. Relative to open standards and regulation, efficiency gains from platform sponsorship might therefore occur in coordination and in specificity.

3 Extensions

It is worthwhile examining the robustness of our analysis to changes in assumptions. Major assumptions include, (1) a point estimate of consumer value, (2) a Cobb-Douglas production function, and (3) a one period useful lifetime for open platform stock and developer applications.

Clearly, and consistent with other papers in the literature, we make the assumption of a point value for consumer demand for tractability. For many information goods delivered as bundles, however, this assumption can become a reasonable approximation (Adams & Yellen, 1976).

The commonly used assumption of Cobb-Douglas production is, again, made for tractability and allows for simple results expressed in terms of constant elasticity of output with respect to changes in technology. Similar conclusions can be obtained with alternate output formulations but results are particularly elegant with the current specification. This model also introduces a novel aspect in which the choice parameter, contractual openness, plays a central role.

The assumption of a one period lifetime for platform and developer stock also makes the analysis more tractable. However, allowing open platform stock to stimulate production for additional periods would increase developer output which should increase the willingness of platform sponsors to open in order to increase the platform sponsors' share of developer surplus. Relaxing this assumption would strengthen the result that platform sponsors find it in their interest to open the platform.

Finally, we point out that the view of platform roles as being cleanly delineated between platform sponsors and application developers may not be the only manifestation of platform systems. In reality, application developers may be platform sponsors in their own products such that platforms can be viewed as nested "Russian Dolls," repeating in smaller layers. In a conceptual framework, Eisenmann, Parker, and Van Alstyne (2007) discuss how different platform systems may share users and compete with one another through platform envelopment.

4 Conclusions

The analysis presented here argues for several simple but important results. First, we show that platform sponsors can control downstream innovation, increasing profits through an optimal choice of openness. They find it privately rational to stimulate production by others even at the cost of sacrificing direct platform sales. The openness condition is determined by the increase in developer output relative to subsidy cost as mediated by the elasticity of output across both periods. This result clarifies strategies of firms that have relaxed platform control after building valuable brands.

Second, analogous to periods of patent protection, we identify conditions for a finite exclusionary period. In our model, this represents the time during which downstream developers can charge for new applications before the sponsor folds these enhancements into the open platform. Platform envelopment of first period innovations should occur at a time determined by the point at which second period developer output exceeds first period output. If second period output is smaller, then it is never optimal to fold developer enhancements into the platform as this reduces first period surplus.

We also analyze the size of the developer pool and the intensity of competition among developers and platforms. More developers leads to a more open platform and also decreases the time until new features become part of the platform. In contrast, increased developer competition reduces openness because it reduces surplus available to the sponsor. More competition also shortens the proprietary period because new value comes relatively more from new production than from existing sales. Increasing platform competition has the opposite effect. Platform sponsors have less direct profit and therefore prefer to increase developer revenues through a more open contract with a longer proprietary period.

Third, the model provides conditions for choosing between competing contract types. To promote sequential innovation, a sponsor can choose closed developer contracts that do not sacrifice platform profits or open contracts that stimulate greater developer participation. Open contracts that lead to decentralized innovation are increasingly preferred when the subsidy cost is smaller, developer output larger, or technology superior. These results are achieved without appeal to transaction costs, which should intrinsically favor open contracts that are simply default offers requiring no negotiation.

Fourth, we demonstrate a prisoners' dilemma where developers individually refuse to open their applications even as they prefer every other developer open theirs. Given a sufficiently large developer pool, however, all developers are better off submitting to a contract forcing them to open their applications. The reason is that subsequent output can build from a larger pool of initial input, leading to higher total surplus. The platform sponsor must enforce such contracts not only for benefit of the platform but of the developers themselves, a role not unlike that of a social planner. This result is of particular importance for regulators and platform systems designers. In order to maximize the value creation potential of a platform system, the platform sponsor must have a longer tenure than the developers who build upon it.

References

[1] Adams, W. J. and J. L. Yellen (1976). "Commodity bundling and the burden of monopoly," *Quarterly Journal of Economics* 90, pp 475-98.

[2] Bessen, J., and E. Maskin. (forthcoming) "Sequential Innovation, Patents, and Imitation." *Rand Journal of Economics.*

[3] Boudreau, K. (2007) "Does Opening a Platform Stimulate Innovation? The Effect on Systemic and Modular Innovations." Available at http://ssrn.com/abstract=913402.

[4] Bresnehan, T. and S. Greenstein (1999). "Technological Competition and the Structure of the Computer Industry," *Journal of Industrial Economics* 47 pp 1-40.

[5] Caillaud, B. and B. Jullien. (2003) "Chicken & Egg: Competition Among Intermediation Service Providers." *Rand Journal of Economics* 34(2).

[6] Chang, H.F. (1995). "Patent Scope, Antitrust Policy, and Cumulative Innovation," *Rand Journal of Economics* 26(1), 34-57.

[7] Cusumano, M. and A. Gawer. (2002). Platform Leadership: How Intel, Microsoft and Cisco Drive Industry Innovation. Harvard Business School Press. Boston, MA.

[8] Eisenmann, T, Parker, G. and M. Van Alstyne. (2007) "Platform Envelopment." Available at http://ssrn.com/abstract=996852.

[9] Farrell, J., Monroe, H. & Saloner, G. (1998) "The Vertical Organization of Industry: Systems Competition vs Component Competition" *Journal of Economics & Management Strategy* 7(2) pp 143-82.

[10] Gilbert & Shapiro (1990). "Optimal patent length and breadth" *Rand Journal of Economics* 21(1), 106-112.

[11] Green, J.R. & S. Scotchmer (1995). "On the division of profit in sequential innovation," *Rand Journal of Economics* 26(1), 20-33.

[12] Klemperer, P (1990) "How broad should the scope of patent protection be?" *Rand Journal of Economics* 21(1), 113-130.

[13] Landes, W. M., R. A. Posner (2003) "Indefinitely Renewable Copyright" *University of Chicago Law Review* 70(2), 471-518.

[14] Parker, G. and M. Van Alstyne (2005). "Two-Sided Network Effects: A Theory of Information Product Design." *Management Science* Vol. 51, No. 10.

[15] Rey, P. and D. Salant (2007). "Abuse of Dominance and Licensing of Intellectual Property." IDEI Working Paper.

[16] Rochet, J.C. and J. Tirole (2003). "Platform Competition in Two-Sided Markets." *Journal of the European Economic Association.*

[17] Shapiro, C. (2001) "Navigating the patent thicket: cross-licenses, patent-pools, and standard-setting" in *Innovation Policy and the Economy*, Vol 1. (eds.) A. Jaffe, J. Lerner, S. Stern; MIT Press.

5 Appendix

5.1 Derivation of Comparative Statics

We use the envelope theorem to establish the effect of exogenous parameters on the platform's optimal choice of σ and δ. For example, by the envelope theorem, Sign[$\frac{\partial\sigma}{\partial k}$] is equal to Sign[$\frac{\partial^2\pi_p}{\partial\sigma\partial k}$].

5.1.1 The effect of V on σ is negative

To determine the sign of $\frac{\partial\sigma}{\partial V}$, take the partial derivative of equation 5 with respect to V to get

$$\frac{\partial^2\pi_p}{\partial\sigma\partial V} = -\frac{k^{\alpha+1}vV^{\alpha^2}\alpha^4(\delta-1)\delta\sigma^{\alpha^2} + kvV^{\alpha}\alpha^2(\delta-1)\sigma^{\alpha} + 2V\sigma}{2V\sigma}.$$

Substituting price, output, and elasticity terms for the model primitives, this can be rearranged as

$$\frac{(1/2)\,p\,y_1}{\sigma V}\eta_1^2 + \frac{(1/2)\,\delta\,p\,y_2}{\sigma V}\eta_2^2 - 1. \tag{19}$$

Note that this differs from Equation 4 only by a square on the elasticity terms. Since both elasticities are less than one, this expression must be negative.

5.1.2 The effect of v on σ is positive

Calculate the cross partial derivative of profit as

$$\frac{\partial^2\pi_p}{\partial\sigma\partial v} = \frac{k\alpha(1-\delta)\left(k^{\alpha}M\mathrm{V}^{\alpha^2}\alpha\delta\sigma^{\alpha^2} + \mathrm{V}^{\alpha}\sigma^{\alpha}\right)}{2\sigma}.$$

Note that all terms are positive.

5.1.3 The effect of k on σ is positive

Take the partial derivative of equation 5 with respect to k to get

$$\frac{\partial^2\pi_p}{\partial\sigma\partial k} = \frac{1}{2}p\sigma^{\alpha-1}V^{\alpha} + \frac{1}{2}\delta pk^{\alpha}\sigma^{\alpha^2-1}V^{\alpha^2}.$$

Since all terms are positive, we conclude that $\frac{\partial\sigma}{\partial k}$ is also positive.

5.1.4 The effect of α on σ is indeterminate

Take the cross partial, combine log terms and substitute y_1 and y_2 for the primitives to get the following equation.

$$\frac{\partial^2\pi_p}{\partial\sigma\partial\alpha} = \frac{v(1-\delta)\left((\alpha\log(V\sigma)+1)y_1 + \alpha\delta\left(\alpha\log\left(kV^{2\alpha}\sigma\right)+2\right)y_2\right)}{2\sigma}$$

The sign of $\log V\sigma$ and $\log kV^{2\alpha}\sigma$ depends upon specific parameter values. Since $0 < \sigma < 1$, $0 < k < \infty$, and $0 < V < \infty$ the sign of $\frac{\partial^2 \pi_p}{\partial\sigma\partial\alpha}$ is indeterminate.

5.1.5 The effect of V on δ is negative

We calculate the following cross partial derivative.

$$\frac{\partial^2 \pi_p}{\partial\delta\partial V} = \frac{v\alpha\left(k^{\alpha+1}MV^{\alpha^2}\alpha(1-2\delta)\sigma^{\alpha^2} - kV^{\alpha}\sigma^{\alpha}\right)}{2V}$$

Substitute y_1 and y_2 for model primitives to get

$$\frac{\partial^2 \pi_p}{\partial\delta\partial V} = \frac{v\alpha\left(y_2\alpha(1-2\delta) - y_1\right)}{2V}.$$

This is negative when $y_2\,\alpha\,(1-2\delta) < y_1$. Divide both sides by y_2 to express this as

$$\alpha\,(1-2\delta) < \frac{y_1}{y_2}.$$

The optimal solution for δ requires that $\frac{y_1}{y_2} = (1-2\delta)$. Given $\alpha < 1$, we conclude that δ falls in V.

5.1.6 The effect of v on δ is negative

The direct calculation of $\frac{\partial^2 \pi_p}{\partial\delta\partial v}$ returns the first order condition for δ and is otherwise inconclusive. So, we analyze the effect of σ on δ to make a statement about the effect of v on δ. Take the optimal expression for δ (Equation 6) and substitute the model primitives for y_1 and y_2 to get the following expression.

$$\delta = \frac{1}{2}\left(1 - k^{-\alpha}V^{\alpha-\alpha^2}\sigma^{\alpha-\alpha^2}\right)$$

Given $0 < \alpha < 1$ we conclude that δ falls in σ. Above, we establish that σ grows in v. Therefore, δ falls in v.

5.1.7 The effect of k on δ is positive

We calculate the following cross partial derivative.

$$\frac{\partial^2 \pi_p}{\partial\delta\partial k} = \frac{1}{2}v\left(k^{\alpha}V^{\alpha^2}(1+\alpha)(1-2\delta)\sigma^{\alpha^2} - V^{\alpha}\sigma^{\alpha}\right)$$

Multiply and divide by k to restore expressions for y_1 and y_2.

$$\frac{v\left((1+\alpha)(1-2\delta)y_2 - y_1\right)}{2k}$$

This is positive by the optimal solution to δ, Equation 6.

5.1.8 The effect of α on δ is indeterminate

Take the cross partial, combine log terms and substitute y_1 and y_2 for the primitives to get the following equation.

$$\frac{\partial^2 \pi_p}{\partial \delta \partial \alpha} = \frac{1}{2} v \left((1 - 2\delta) \log \left(k V^{2\alpha} \sigma \right) y_2 - \log(V\sigma) y_1 \right)$$

The sign of $\log V\sigma$ and $\log kV^{2\alpha}\sigma$ depends upon specific parameter values. Since $0 < \sigma < 1$, $0 < k < \infty$, and $0 < V < \infty$ the sign of $\frac{\partial^2 \pi_p}{\partial \delta \partial \alpha}$ is indeterminate.