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Zhizhong Patrick Zhou
University of California, Irvine

Kevin Zhu
University of California

PLATFORM BATTLE WITH LOCK-IN

Economics and Information Systems

Zach Zhizhong Zhou
Paul Merage School of Business
University of California, Irvine
zhouz@uci.edu

Kevin Zhu
Rady School of Management
University of California, San Diego
kxzhu@ucsd.edu

Abstract

Many services and applications run on platforms, such as operating systems, Web service platforms, and video game consoles. "Lock-in customers and locking-out competitors" is an important strategy for platform providers, who can lock in adopters by creating substantial cross-platform switching costs (e.g. by creating incompatibility and reducing interoperability). This paper examines whether such lock-in strategy benefits proprietary platform providers. Using a two-period duopoly model in which platform adopters are heterogeneous in their tastes and willingness-to-pay, we give conditions under which the lock-in strategy benefits or hurts platform providers. When a proprietary platform competes against an open-source-based platform, the proprietary platform should not lock-in its adopters. But if the platform battle is between two proprietary platforms, platform providers should lock-in adopters if the following two parameters are sufficiently large: (i) the adopter's lowest willingness-to-pay and (ii) the relative dispersion of adopter willingness-to-pay. Lastly, this paper shows how naïve adopter expectations affect the platform provider's incentives to lock-in adopters.

Keywords: Lock in, switching costs, proprietary and open-source platforms

Introduction

Today many services and products are organized around platforms. These platforms compete in various markets. Examples include Windows and Linux (operating systems), J2EE and Microsoft's .NET (Web service platforms), Microsoft's Xbox360 and Sony's PS3 (video game consoles), Microsoft's Internet Explorer (IE) and Mozilla's Firefox (Internet browsers), Intel's Vivi and Apple's Sonos (digital entertainment platforms), and Real Player, Media Player, and QuickTime (media players).

In some markets, consumers can easily switch from one platform to another (e.g. Internet browsers). Yet many platforms are characterized with a phenomenon called *lock-in*, which ties platform adopters on a single platform with high switching costs that can be endogenously generated by a platform provider (Klemperer 1995). Thus, "lock in customers and lock out competitors" can be a firm's deliberate strategy (Klemperer 1987a, Chen and Hitt 2002). Take the computer industry as an example: a platform provider may lock-in adopters in many ways: (1) using proprietary data storage formats that lack interoperability with other platforms; (2) designing a platform incompatible with hardware and software developed by other platform providers; or (3) licensing the platform under the condition that adopters do not use other platforms (Kucharik 2003).

Microsoft is allegedly employing the lock-in strategy. Its Web service platform .NET was widely seen as another name for lock-in (Berinato 2005). As Jonathan Schwartz, chief strategy officer for Sun, argued that "*Microsoft is going to operate a Web services network, not just the software tools to build applications. Its business model is to lock in corporate customers and consumers*" (Lohr 2002). Potential adopters worried that if .NET only worked on Microsoft's Windows platform, they might be required to replace their existing IT assets to create a homogeneous Microsoft IT server environment. IBM warned that "*Microsoft has built its business on a model that forces customers to spend money on software upgrades every few years. Every successive upgrade restricts Microsoft's client base to fewer options and increased dependence on its platform*" (IBM 2004). Apparently the purpose of lock-in is to obtain a monopoly power over locked-in adopters, and to exploit them in the future. This is why Microsoft's "embrace-and-extend" strategy is often derided as "engulf-and-devour" strategy.

For many years, customers and vendors have been worried about this "lock-in" business model. As a response, the *open source movement* is gaining momentum in the software industry. Open source refers to the free distribution, modification, and usage of software source codes. For example, J2EE, the .NET's rival, is an open-source Web service platform accessible to, and supported by, many vendors. Its openness encourages interoperability. IBM argued that J2EE adopters would not be locked-in because they have the choice of vendor products and tools (IBM 2004). The open source movement is being promoted by governments, especially in developing nations such as India, China, and Brazil. The Indian government promotes the open source with a belief that India has a good pool of IT talent that other developing countries cannot match. The Chinese government backs the open source to avoid continuously feeding cash to proprietary platforms after locked-in. (Marson 2005). Facing the open source competition, should a platform provider such as Microsoft still continue to employ a "lock-in" strategy?

Competition comes not only from open-source platforms but also from other proprietary platforms. The grid computing market has a number of competing proprietary platforms, such as Microsoft's Dynamic Systems Initiative (DSI), IBM and CA's on-demand computing, Hewlett-Packard's Adaptive Enterprise, Sun's N1, and Oracle's Grid Computing. These platforms are not interoperable with each other (at least in their current forms), and may lead to vendor lock-in (Longworth 2004). In the video game console market, Sony's Play Station is the major proprietary opponent of Microsoft's Xbox; the next-generation DVD standards have split the industry into two camps: Blu-ray backed by Sony and HD-DVD backed by Microsoft. Both standards are so different that it is infeasible to design a single platform to support both. Such incompatibility generates high cross-platform switching costs, which may enable vendors to lock in their customers and then charge high prices for video games and platform upgrades. In the digital music player market, Apple's iPod uses a DRM (digital rights management) scheme different from that of Microsoft's Origami. Music purchased from Apple's iTunes online store cannot be directly played on Microsoft's Origami. Thus, lock-in is highly likely (Miller, 2005). Apple currently charges 99 cents per download on its iTunes online store (partly to drive iPod sales), but it may charge higher prices once a big number of iPod users are locked in. Other examples include locking consumers in a specific channel (Viswanathan 2005) or to a specific online service provider (Chen and Hitt 2002).

The lock-in issues illustrated by these examples give rise to a set of critical research questions regarding its effects on platform providers and adopters.

- To compete against a zero-price, open-source platform, is it optimal for a proprietary platform to use the "lock-in" strategy?
- When the competition is between two proprietary platforms, should both always lock in their adopters?

This paper uses a simple two-period duopoly model to examine these research questions. Platform adopters are heterogeneous in terms of both their tastes and their willingness-to-pay. Intuitively locking in adopters enables a proprietary platform to obtain monopoly profits in the post-adoption period (period 2). But two effects are associated with the lock-in strategy. First, rational adopters foretell a high monopoly price in the future. Then they would be reluctant to adopt a platform with lock-in, or ask for an extremely low "introductory price" in the pre-adoption period (period 1). Thus, the lock-in strategy might not always be beneficial to platform providers. Second, platform providers realize that if they have larger market shares in period 1, they would have higher monopoly profits in period 2. Consequently, they would aggressively fight for the market share in period 1. Such fierce competition could hurt platform providers. Overall it is not clear under what specific conditions the lock-in benefits or hurts platform providers. Therefore, a rigorous model is needed to analyze our research questions.

Related Literature

This paper is related to a stream of literature on switching costs (see Farrell and Klemperer 2004 for a review). Most studies (Klemperer 1987a, 1987b, 1995; Mariñoso 2001; Caminal and Matutes 1990; Kim et al. 2001, Viswanathan 2005) considered the competition between two proprietary platforms, but little is known about the competition between an open-source platform and a proprietary platform with lock-in. Recently, there is an emerging literature on open source (Lerner and Tirole 2002; Mustonen 2002; Frost 2005), but few studies consider the lock-in strategy in the context of platform competition where a zero-price, open-source platform is involved.

In addition, earlier studies only considered one-dimensional heterogeneity in adopters (i.e., preferences). For mathematical tractability, these papers assumed that consumers had the same reservation price, which was sufficiently high to ensure that none was priced out of the market. In reality, however, some of the low-end adopters can be priced out of the market after being locked-in (IBM 2004; Farrell and Klemperer 2004). The reason is that a proprietary platform characterized with lock-in has a lower price in period 1 and a higher price in period 2 (Klemperer 1995). Also, firms with higher willingness-to-pay (say, larger firms) and firms with lower willingness-to-pay (say, smaller firms) exhibit different adoption patterns (Gartner 2003). This motivates us to introduce another parameter, adopter willingness-to-pay, to represent this heterogeneity among adopters. Comparing with prior studies, this will allow us to examine the relationship between adopter heterogeneity in willingness-to-pay and platform providers' incentives to use the lock-in strategy. [1]

Platform providers may lock-in adopters by deliberately creating switching costs that can be "artificial," such as offering coupons (Caminal and Matutes 1990) and providing rewards (Kim, et al. 2001), or be "real," such as producing incompatible components in the future period (Mariñoso 2001). In this paper, platform providers, if they want to lock-in adopters, generate incompatibility among platforms or reduce interoperability with other platforms in period 1.

The Model: A Two-period Game

Two platform providers, named A and B, license their platforms with a zero marginal cost. Platform A and B compete in licensing prices in each period. Prices are announced simultaneously. Both platform providers cannot set prices based on adopters' types, either because they are unable to observe adopters' types, or because they are prohibited from price discrimination. If B is an open platform rather than a proprietary platform, we denote it by O rather than B. The open platform's licensing price is always zero; the proprietary platform provider cannot pre-commit her second-period price[2]. In practice, the pre-commitment can lead to opportunism (Farrell and Shapiro 1989). The uncertainty about future upgrades and platform enhancements makes the price pre-commitment incredible. Even though the proprietary platform provider pre-commits her future price, she may add new features on the legacy platform, and then charge locked-in adopters for upgrading services. Microsoft often changes its programming models so that it has an opportunity to charge locked-in adopters for training their software engineers. For simplicity, we assume that the sum of other costs, such as contract costs and maintenance costs, is the same for adopting either platform A or B (O) and is normalized to zero. Therefore, the cost of adopting a platform equals to that platform's licensing price.

A group of platform adopters of measure 1 and two competing platforms stay in the market for two periods. Each adopter adopts at most one platform in each period. Adopters are represented by parameters (r,θ), where r is an adopter's willingness-to-pay, and θ is her taste (see Figure 1).

Adopters have heterogeneous tastes because both platforms are differentiated in terms of their features. For example, J2EE has a better legacy integration story than .NET; the average salary of .NET (or C#) developers is lower than that of J2EE (or JAVA) developers; J2EE is supported by the entire industry of 50+ assorted vendors while .NET is supported by Microsoft only. Adopters are heterogeneous in their willingness-to-pay for many reasons. For instance, average adopters in developing nations have lower willingness-to-pay than those in developed nations; companies with losses have lower willingness-to-pay than those with high profits.

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[1] The idea of two-dimensional heterogeneity in consumers is related to Tyagi (2004). But Tyagi studied the effects of transaction cost reduction on consumers, who have heterogeneous valuation of quality and transaction costs reduction. It was a different research topic from ours.

[2] If the price commitment is credible, Von Weizsäcker (1984) has shown that the presence of switching cost makes the market more competitive. But if the price commitment is incredible, Klemperer (1987b) indicates that switching costs could reduce the competitiveness of the market. Bensaid and Lesne (1996) have shown the difference between price pre-commitment and non-pre-commitment.

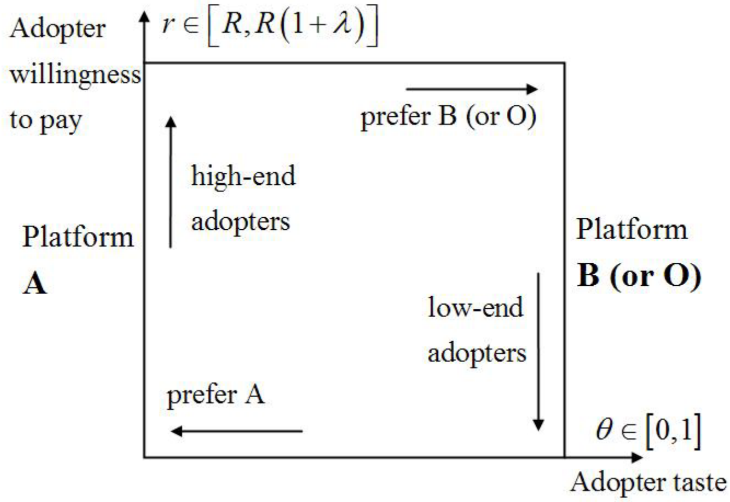

Figure 1: The Distribution of Adopters

The adopter taste (θ) is uniformly distributing with unit density on $[0,1]$. Platform A is located at 0 while B (or O) is located at 1. The adopter willingness-to-pay (r) is independent of θ and uniformly distributing on $[R,(1+\lambda)R]$ with a density function $1/(\lambda R)$. These assumptions ensure that the market size is 1. We assume $0<\lambda\le 1$, implying that the highest willingness-to-pay is at most two times as the lowest willingness-to-pay. Since $\lambda=\lambda R/R$, the dispersion of willingness-to-pay divided by the lowest willingness-to-pay, we call λ *relative dispersion*. Further, we assume $R\ge 1$ to ensure that the open-source-based platform is always affordable to *all* adopters. Platform providers can charge their platform adopters directly or indirectly. For example, Microsoft may *directly* charge gamers for Xbox360 video game consoles. Microsoft also licenses Xbox360 to game developers. The license fees charged on game developers are shouldered by final users – gamers. In the latter case, Microsoft *indirectly* charges gamers for the platform. We ignore the difference between direct pricing and indirect pricing hereafter by simply stating that platform adopters shoulder the total price charged to them and to intermediaries[3]. Denote by p_{it} $(i=A,B,O;\ t=1,2)$ platform *i*'s *t* period total price charged to adopters. If an adopter indexed with (r,θ) adopts A, she gets a net surplus $\max(r-\theta-p_{At},0)$ in period *t*. If she adopts B, then her *t*-period surplus is $\max(r-(1-\theta)-p_{Bt},0)$. An adopter's *total net surplus* is the discounted sum of her net surplus in two periods with discount factor $\delta=1$. Platform providers have the same discount factor $\delta=1$.

The sequence of events occurs as follows. In period 1, platform providers determine whether to promote compatibility by signing cross licensing agreements or working together to develop and adopt industry standards. If yes, adopters can freely switch between two platforms; otherwise both platforms are characterized with lock-in where adopters cannot switch to the other platform in the second period. After that, platform providers announce p_{i1} simultaneously (note $p_{O1}=p_{O2}=0$). Given p_{i1} , rational adopters can derive p_{i2} . Comparing the total net surplus deriving from each platform, adopters make adoption decisions in period 1. An adopter may continue to use the platform adopted in period 1, switch to the other platform (if there is no lock-in), or quit the market (if she cannot afford any p_{i2}).

[3] We assume that the demand of platform adopters only depends on the aggregate price level charged to them rather than on the allocation of this total price between them and the intermediaries. Thus, this paper only focuses on lock-in effects rather than on two-sided network effects as in Rochet and Tirole (2004).

Open Platform Versus Proprietary Platform (A vs. O)

First, we consider the platform battle between an open source platform (denoted by O) and a proprietary platform (denoted by A) characterized with lock-in. Platform A's provider is able to charge a monopolist price over locked-in adopters in period 2, then some of A's adopters can be priced out of the market. On the other hand, platform O is affordable to all adopters in both periods. Therefore, there are two types of adopters: (1) those who can afford p_{A1} and p_{A2}, and (2) those who can afford p_{A1} only.

The marginal type 1 adopters satisfy $2r-2\theta-p_{A1}-p_{A2}=2r-2(1-\theta)$, or $\theta=\theta_{A2}=(2-p_{A1}-p_{A2})/4$. The marginal type 2 adopters satisfy $r-\theta-p_{A1}=2r-2(1-\theta)$, or $\theta=(2-r-p_{A1})/3$. Figure 2 illustrates the adoption pattern for A vs. O.

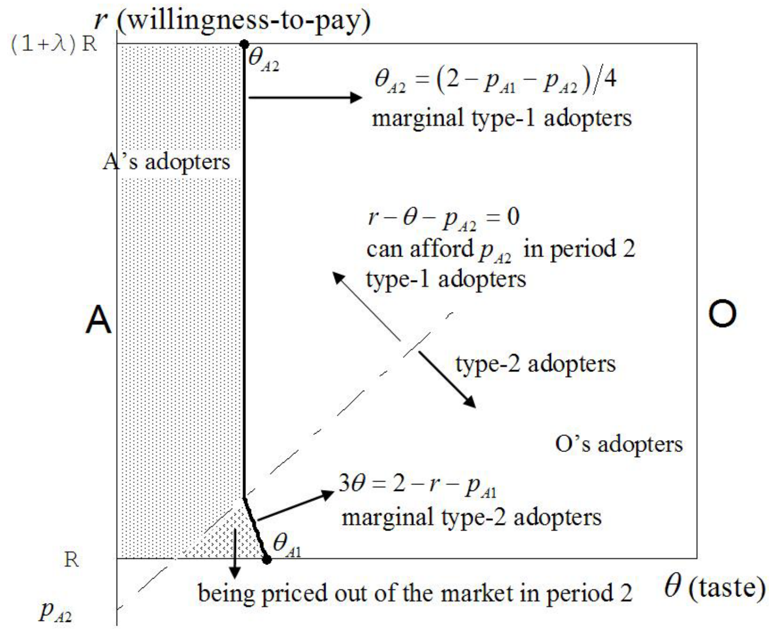

Figure 2: The Adoption Pattern for A vs. O

Clearly, platform A captures a greater number of low-end adopters than high-end adopters. This result seems quite counterintuitive. High-end adopters are not afraid of being priced out of the market, while low-end adopters can be priced out of the market in period 2. Why does platform A capture a greater number of low-end adopters rather than high-end adopters? The reason is as follows. Rational adopters know $p_{A2}>0=p_{O2}$; they will ask for a $p_{A1}<0$ [4] to compensate their losses in period 2, otherwise they will adopter O with $p_{O1}=p_{O2}=0$. The steep discount in period 1 is a free meal for adopters. While high-end adopters are exploited by platform A in period 2, low-end adopters may just "eat and run". Thus, low-end adopters can obtain more surplus from adopting A in period 1 than from adopting O in both periods. This explains why platform A can be more attractive to low-end adopters. As figured out by Gartner (2003) and Forrester (2005), small and medium enterprises prefer Microsoft's .NET to J2EE. The reason might be that Microsoft's steep discount attracts lower-end adopters (Fuller 2003).

Given the adoption pattern, we proceed to solve p_{A1} and p_{A2} using a backward induction. Denote platform A's market share in the high-end market by θ_{A2}, we have

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[4] Note that the marginal cost of licensing the platform is normalized to zero. $p_{A1}<0$ means that platform A charges a price *lower than its marginal cost*. In practice, the price of Microsoft's Xbox360 was lower than the marginal cost; wireless phone service providers offer free cell phones to consumers who commit to purchase their service plans.

LEMMA 1. *The proprietary platform A's second-period price* p_{A2} *is*

$$p_{A2} = \frac{1}{3}\left[2R - 2\theta_{A2} + \sqrt{\left(R-\theta_{A2}\right)^2 + 6\lambda R\theta_{A2}}\right]. \tag{1}$$

Adopters are rational and foresighted. After p_{A1} is announced, high-end adopters form correct expectations before making adoption decisions (Katz and Shapiro 1985), implying that $\theta_{A2} = \left(2 - p_{A1} - p_{A2}\right)/4$ and (1) hold simultaneously. Solving this equation system for p_{A2} and θ_{A2} yields $p_{A2} = p_{A2}\left(p_{A1}\right)$, $\theta_{A2} = \theta_{A2}\left(p_{A1}\right)$. Hence, π_{A2} can be expressed as $\pi_{A2}\left(p_{A1}\right)$, and platform A's total profit can be written as

$$\pi_A = \pi_{A1} + \pi_{A2} = d_{A1}\left(p_{A1}\right)\cdot p_{A1} + \pi_{A2}\left(p_{A1}\right),$$

where $d_{A1}\left(p_{A1}\right)$ is platform A's demand in period 1. Solving the F.O.C. yields p_{A1}. There is no closed-form solution for p_{A1} though. But if $R \to \infty$, we have the following simple analytical expressions.

LEMMA 2: *Platform A's equilibrium prices in periods 1 and 2 are, respectively:*

$$p_{A1} = \left(15+\lambda\right)/\left[2\left(6+\lambda\right)\right] - R, \tag{2}$$

$$p_{A2} = 3\left(\lambda-1\right)/\left[2\left(6+\lambda\right)\right] + R,\ \pi_A = 3/\left[2\left(6+\lambda\right)\right].$$

It can be shown that (2) is a reasonable approximation of p_{A1} as long as R is sufficiently large.

To examine whether the lock-in strategy helps the provider of the proprietary platform A, we further construct the results for the platform battle between A and O without any switching costs. It is straightforward to get $p_{A1}^N = p_{A2}^N = 1/2$, $\pi_A^N = 1/4$, where the superscript "N" stands for "no switching costs". Numerical experiments show that $\pi_A \le \pi_A^N$ (see Figure 8 in Appendix). Proposition 1 gives a rigorous proof.

PROPOSITION 1: *Considering the platform battle between an open-source-based platform and a proprietary platform, the proprietary platform provider should not lock in its adopters.*

It should be note that Proposition 1 does not depends on Lemma 2 and the assumption $R \to \infty$. We prove this Proposition without deriving analytical solution of π_A. The intuition of Proposition 1 is as follows. The open platform is able to commit its second-period price $\left(p_{O2} = 0\right)$. Such price commitment is platform O's key advantage over platform A since platform A is unable to pre-commits p_{A2}. Foresighted adopters know that if they adopt platform A, they will be heavily exploited in period 2. To attract adopters, platform A needs to set a substantially low p_{A1}. But a low p_{A1} not only attracts higher-willingness-to-pay adopters but also some lower-willingness-to-pay adopters who will be priced out of the market in period 2. That is, platform A captures some unworthy adopters, who cannot be exploited in period 2. Such allocation inefficiency is mainly due to platform A's inability to pre-commit her second-period price. The proof of Proposition 1 shows that if A were able to commit p_{A2}, she is better off by charging the same price in both periods.

In an identical market without any switching costs, adopters are myopic because they are not afraid of being locked-in. In this case, price commitment is worthless to platforms. Platform O's strength disappears. Therefore, platform A can get a higher profit than that when it locks-in adopters.

Platform Battle between Two Proprietary Platforms (A vs. B)

In this section, we focus on the symmetric equilibrium (see Figure 3) with $\theta_{A1} = \theta_{A2} = 1/2$. The backward induction is used to derive p_{i1} and p_{i2} $(i = A, B)$. Substituting $\theta_{A2} = 1/2$ into (1) yields $p_{A2} = p_{B2} = p_2$. Platform A's total profit is $\pi_A = \pi_{A1}(p_{A1}, p_{B1}) + \pi_{A2}(\theta_{A2})$. Solving $d\pi_A/dp_{A1} = d\pi_{A1}/dp_{A1} + (d\pi_{A2}/d\theta_{A2}) \cdot (d\theta_{A2}/dp_{A1})$ and $p_{A1} = p_{B1} = p_1$ for p_1 yields equilibrium prices in period 1.

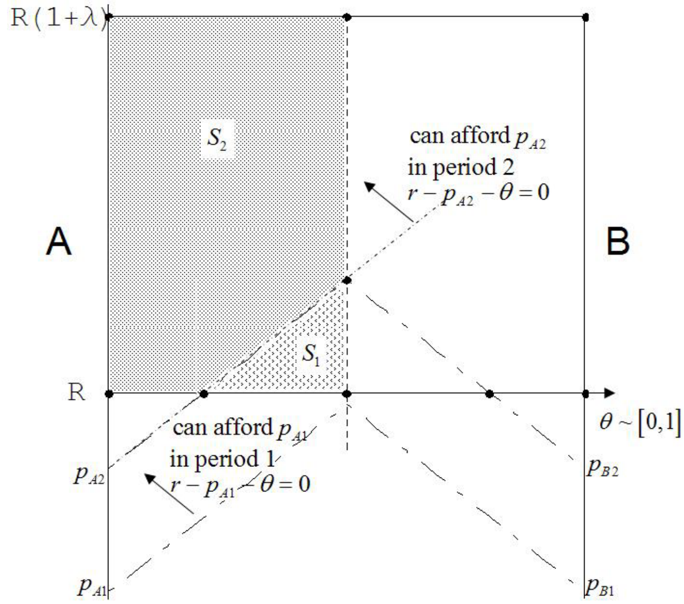

Figure 3: The Symmetric Equilibrium for A vs. B with Lock-in

LEMMA 3: *Considering the platform battle between two proprietary platforms A and B, the licensing prices at the symmetric equilibrium are as follows.*

$$p_{A2} = p_{B2} = p_2 = \frac{1}{6}\left(4R - 2 + \sqrt{(2R-1)^2 + 12v}\right), \tag{3}$$

$$p_{A1} = p_{B1} = p_1 = \frac{wu_1 + u_0}{12(wx_1 + x_0)}, \tag{4}$$

where $u_1 = 5(2R-1)^3 - 72v^2 - 6v(44R^2 - 80R + 29)$, $u_0 = -\left[(2R-1)^2 + 12v\right]\left[4R(5R + 48v - 5) - 504v + 5\right]$,

$x_1 = 2\left[(2R-1)^2 + 6v\right]$, $x_0 = -\left[(2R-1)^2 + 12v\right](4R - 27v - 2)$, $w = \sqrt{(2R-1)^2 + 12v}$, and $v = \lambda R$.

Further, if $R \to \infty$, *then* $p_{A1} = p_{B1} = 2 + \lambda/2 - R$, $p_{A2} = p_{B2} = R - (1-\lambda)/2$, $\pi_A = \pi_B = 3(2+\lambda)/8$.

Considering the platform battle without any switching costs, it is straightforward to obtain $p^N_{A1} = p^N_{A2} = p^N_{B1} = p^N_{B2} = 1$, $\pi^N_A = \pi^N_B = 1$, where the superscript "N" represents "no switching costs".[5] Comparing these results with Lemma 3, we have:

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[5] If there are no switching costs, adopters care only about the payoff in the current period because they can freely switch to another platform in the future. Marginal adopters (r, θ_1) satisfies $r - \theta_1 - p_{A1} = r - (1-\theta_1) - p_{B1}$. Platform A's problem is

PROPOSITION 2: *Considering the competition between two proprietary platforms A and B, lock-in benefits both platform providers as long as λ and R are sufficiently large (i.e., $\lambda > \hat{\lambda}$ and $R > \hat{R}$); otherwise lock-in hurts both platform providers*.

Here $\hat{R}$ and $\hat{\lambda}$ represent the threshold values. The specific values of $\hat{R}$ and $\hat{\lambda}$, as well as the comparative statistics are given in Appendix. We use them to explain the intuition of proposition 2. [6] If both platforms are characterized with lock-in, then $d\pi_{A2}/d\theta_{A2}|_{R\to\infty} = R - 1 + (\lambda/2) > 0$ (the monopoly profit in period 2 increases with θ_{A2}). Hence, platform providers have incentives to fight for larger market share in period 1. Note that $dp_{A2}/d\theta_{A2}|_{R\to\infty} = \lambda - 1 \le 0$ (the second-period price decreases with θ_{A2}). Foresighted adopters realize that a lower price in period 1 implies a lower price in the future $(p_{A1} \downarrow \to \theta_{A2} \uparrow \to p_{A2} \downarrow)$. Thus, the demand elasticity is greater than that in an identical market without any switching costs[7]. Platform providers would find that it is easier to capture adopters in period 1 by lowering their first-period prices. Consequently, the lock-in could trigger a price war in period 1 and then intensify the overall competition, making both platform providers worse off than there are no switching costs.

On the other hand, a larger λ (the relative dispersion) makes it more difficult for platform providers to capture high-end adopters by lowering the first-period price. This fact can be illustrated by $|d\theta_{A2}/dp_{A1}| = 3/(6+4\lambda)$, which is a decreasing function of λ. As a result, platform providers would be less aggressive in fighting for the market when they realize that it is difficult to do so. Consequently, the overall competition can be softened; and the lock-in strategy can benefit platform providers.

Finally, a small *R* tends to reduce platform provider's desirability to lock in her adopters. The intuition is as follows. In the platform battle with lock-in, platform providers lose some demands in period 2 because some of the low-end adopters will be priced out of the market. If *R* is sufficiently large, the monopoly profits obtained from high-end adopters can cover the losses of losing low-end adopters' demands. But if *R* is small, platform providers only get a low profit margin from each locked-in adopter; and the monopoly profit is too low to compensate the demand loss. In such case, each adopter is worthy to platform providers. Thus, platform providers should capture all of them in both periods, and the lock-in strategy should be rejected.

Proposition 2 generates important managerial implications to platform providers. First, the lock-in strategy does not always benefit platform providers because it could intensify the overall competition. Second, platform providers only lock-in adopters under the following conditions: (1) the market parameters reduce the overall competition with lock-in, and (2) the monopoly profits in the post-adoption period are sufficiently high to compensate the allocation inefficiency generated by the lock-in.

Myopic Adopters

The above analysis assumes that adopters are foresighted and make adoption decisions based on their payoffs in two periods. Yet not all adopters are foresighted in the real world. For example, if a CIO has a better performance in the current period, her value in the external or internal labor market would increase. In such case, the CIO might only

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$\max_{p_{A1}} p_{A1}\theta_1$. Platform B's problem is $\max_{p_{B1}} p_{B1}(1-\theta_1)$. The Nash equilibrium for this game is $p_{A1} = p_{B1} = 1$ and $\theta_1 = 1/2$. It is easy to verify that nobody is priced out of the market in period 1. Similarly, $p_{A2} = p_{B2} = 1$, $\theta_2 = 1/2$, thus $\pi_A^N = 1$.

[6] It should be note that the proof of Proposition 2 does not depend on $R \to \infty$. The analytical expressions of comparative statistics are complicated, while expressions for $R \to \infty$ are quite simple. Thus we use them for presentation only.

[7] The demand elasticity of high-end adopters is $(\eta_L | R \to \infty) = \dfrac{d\theta_{A2}/\theta_{A2}}{dp_{A1}/p_{A1}} = -\dfrac{3(4-2R+\lambda)}{6+4\lambda}$ in the platform battle with lock-in, and $\eta_N = -1$ in the platform battle with zero switching costs. Apparently $|\eta_L| > |\eta_N|$.

care about the current payoff of adopting a platform. She can switch to another company to get a better pay, even though the former company is locked-in and ripped-off by the platform provider in the second period. Also, adopters could be myopic when they are misled by advertisements to believe that there is no risk of being locked-in.

We consider a simple case where all adopters are myopic. Then an adopter (r,θ) would compare $U_A(r,\theta)=\max(0,r-\theta-p_{A1})$ and $U_B(r,\theta)=\max(0,r-1+\theta-p_{B1})$ (noting that $p_{B1}=0$ if platform B is an open-source-based platform). If $U_A(r,\theta)\ge U_B(r,\theta)$, the adopter would adopt platform A, otherwise adopt platform B. It should be noted that we only assume that adopters are myopic; proprietary platform providers are still foresighted. They would use total profits in both periods, rather than profits in the first period, for comparison when they decide whether to lock-in adopters.

PROPOSITION 3: *If adopters are myopic,*

1) *Platform A would lock-in its adopters if the platform battle is A vs. O*;
2) *Platform A and B would not lock-in their adopters if the platform battle is A vs. B.*

As highlighted earlier, platform O can pre-commit her second-period price, and thus has a competitive advantage over platform A. But if adopters are myopic and do not care about their second-period payoffs, price commitment is not useful any more. It would be easier and less costly for platform A to compete against platform O. Comparing with platform O, platform A's strength is that she may aggressively fight for the market in period 1 by charging a negative price while platform O cannot do so. Platform A's strength is not affected no matter whether adopters are myopic or foresighted. Proposition 3 shows that when platform O loses her strength in the platform battle with lock-in, platform A would use the lock-in strategy.

Recall that if adopters are foresighted, then proprietary platform A and B would lock in these adopters when λ and R are sufficiently large (see Proposition 2). But Proposition 3 indicates that proprietary platforms would not lock-in adopters regardless of the value of λ and R. These results suggest that the competition with lock-in is more intensified when adopters are myopic than when they are foresighted. To understand it, consider a platform battle with lock-in and let platform A deviate from p_{A1} to $p_{A1}-dp_{A1}$ $(dp_{A1}\to 0, dp_{A1}>0)$. The price cut enables platform A to capture a larger market share. Consider a high-end marginal adopter $(r,1/2+d\theta_{A2})$ with r sufficiently large. If the adopter is foresighted, she calculates her incremental disutility (that is, $-d\theta_{A2}$) twice. But if she is myopic, the second-period's disutility is ignored. Hence, myopic adopters are more sensitive to price cut in period 1 than foresighted adopters. Consequently it is easier to capture myopic adopters by cutting p_{A1} than to capture foresighted adopters. Hence, platform providers have greater incentives to fight for the market by cutting p_{i1} $(i=A,B)$. Realizing that the lock-in triggers a more intensified competition, both platform providers would not lock-in their adopters.

Conclusions

This paper shows the implications of lock-in to platform providers in two scenarios: (1) A vs. O: the platform battle between an open-source based platform and a proprietary platform, and (2) A vs. B: the platform battle between two proprietary platforms.

One might think that the lock-in always helps platform providers. We use a two-period model to show that this seemingly intuitive conclusion does not always hold. The lock-in strategy has two effects: (1) it enables platform providers to heavily exploit adopters in the post-adoption period, and (2) it intensifies the platform competition in the pre-adoption period. Comparing with the scenario without any switching costs, the first effect helps platform providers while the second effect is opposite to the first effect.

We construct conditions under which the lock-in strategy hurts or benefits platform providers. If the platform battle is A vs. O, the proprietary platform should not lock-in its adopters. The key reason is that the lock-in strategy leads to *allocation inefficiency*, making it difficult for the proprietary platform to capture desirable adopters. For example, Microsoft has been cooperating with its rival IBM to develop and promote the open Web service standards, such as XML, SOAP, UDDI, and WSDL. These standards are supported by both .NET and J2EE (Vawter and Roman 2001), constructing a solid foundation for the interoperability of .NET and J2EE (Microsoft 2004). "Once dreaded by CIOs as Microsoft's next big lock-in strategy, .Net is now applauded by CIOs as a nice development framework that fosters the technology neutrality they're learning to expect" (Berinato 2005). Therefore, our analytical finding is consistent with the recent trend of increasing interoperability between .NET and J2EE Web-service platforms.

On the other hand, if the platform battle is A vs. B, platform providers should examine whether the lock-in strategy intensifies the overall competition. Our model shows that different market environment parameters have different impacts on the overall competition. The relative dispersion of adopter willingness-to-pay and the lowest willingness-to-pay, which are measured by λ and R respectively, tend to reduce the overall competition if both of them are sufficiently large. If enterprise adopters are highly heterogeneous or they cannot correctly estimate the value of a platform, λ would be large. The willingness-to-pay of enterprise adopters is generally greater than that of home users. Our analytical results suggest that λ and R could be large in some enterprise platform market, such as statistical platform and business intelligence platform markets, where platform providers have incentives to lock-in their adopters. However, little empirical literature studies the relationship between λ (or R) and the platform providers' incentives of using the lock-in strategy. We hope that our model constructs a theoretical base for future empirical research.

Whether adopters are foresighted or myopic can influence the proprietary platform's lock-in strategy. Facing the competition from an open-source-based platform, the proprietary platform does not lock-in foresighted adopters but would lock-in myopic adopters to obtain greater profits. This interesting finding suggests that a proprietary platform has incentives to mislead adopters into believing that there is no risk of being locked-in[8]. Microsoft stated that its XML schema (WordML), which would be implemented in the next generation of Office technologies, was "100 percent compliant with industry standards for XML". Microsoft also claimed that it was "committed to open standards such as XML to provide the highest levels of interoperability between legacy and next-generation software" (Microsoft 2005). However, analysts pointed out that only two out of six MS Office versions supported XML schema, and Microsoft's WordML was only supported by Microsoft's proprietary APIs (Application Programming Interface) and XML-creation tools (The Register 2003). That is, Microsoft is selling its MS Office with lock-in under the veil of "openness" and "interoperability". It means that "fooling adopters" and "locking-in adopters" should be used at the same time. Otherwise, the lock-in strategy itself does not help Microsoft.

If the platform battle is between two proprietary platforms (A vs. B), platform providers wish adopters to be foresighted and rational. Otherwise, the lock-in strategy always intensifies the overall competition and hurts both platform providers.

The above results must be understood within the limitations of our model. This paper focuses on the "lock-in" by assuming that the switching costs are sufficiently large to forbid cross-platform switching. We do not explicitly consider the case where switching costs are finite and small. There are two reasons. First, if switching costs are endogenous, managers are more interested in whether to lock-in adopters than what are optimal switching costs. Thus, explicitly considering small switching costs does not add many business insights to this paper. Second, solving the model with small switching costs can yield mixed strategy equilibra. Shilony (1977) obtained complicated results in a setting with homogeneous consumers who have no preferences and who have the same switching costs and willingness-to-pay. Thus, it is even more intractable to solve for mixed strategy-equilibra in a setting with two-dimensional heterogeneity in adopters. We leave this task in our future research. Zhu (2004) and Zhu and Weyant (2003) considered adoption and investment decisions under asymmetric information. It might be interesting to extend our model to asymmetric cases. We hope that the initial work presented in this paper will motivate other researchers to build more sophisticated models and empirically test our findings.

[8] If adopters are not aware of the risk of lock-in, they will be myopic rather than foresighted.

Appendix

Lemma 1: A vs. O, Platform A's Monopoly Price in Period 2

There are two possible scenarios in period 2: $R\lambda \ge \theta_{A2}$ and $R\lambda < \theta_{A2}$. In the first scenario $R\lambda \ge \theta_{A2}$, there are two sub-cases: $R-\theta_{A2} \le p_{A2} \le R$ and $R \le p_{A2} \le R(1+\lambda)-\theta_{A2}$.

The case $p_{A2} < R-\theta_{A2}$ is impossible because A's second-period profit $\pi_{A2}\big|_{p_{A2}=R-\theta_{A2}}$ is always greater than $\pi_{A2}\big|_{p_{A2}<R-\theta_{A2}}$. The case $p_{A2} > R(1+\lambda)-\theta_{A2}$ is impossible because no adopter with $\theta=\theta_{A2}$ is able to afford A in period 2, violating the assumption that some adopters with $\theta=\theta_{A2}$ can afford A in period 2.

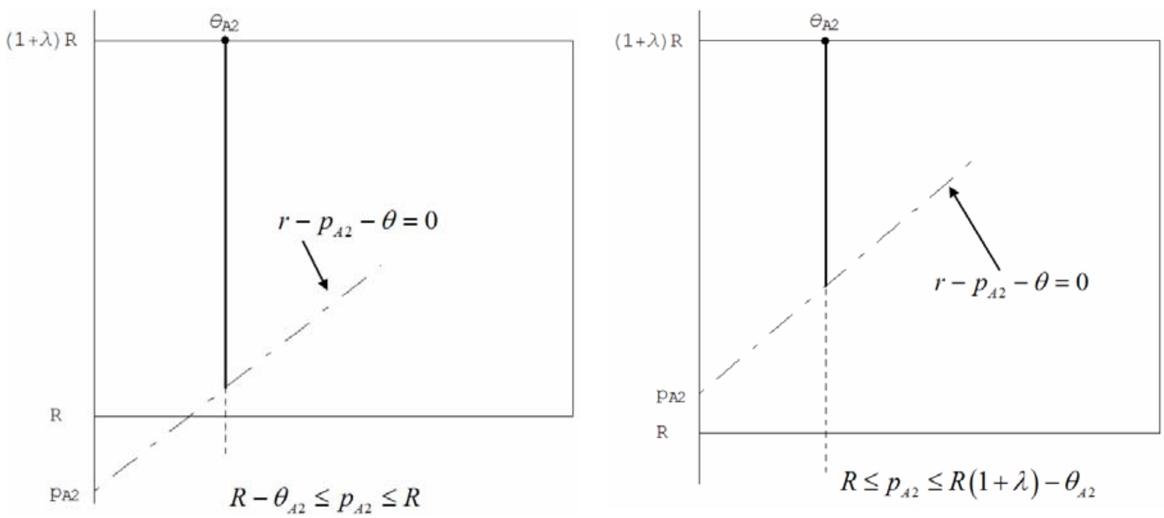

Figure 4: Two Possible Sub-Cases in Period 2

If $R \le p_{A2} \le R(1+\lambda)-\theta_{A2}$, then $\pi_{A2} = \frac{1}{\lambda R}\left(\frac{1}{2}\theta_{A2}^2 + \left[\lambda R - \left(p_{A2} - R + \theta_{A2}\right)\right]\theta_{A2}\right)\cdot p_{A2}$. Solving the F.O.C. yields $p_{A2} = \frac{1}{4}\left(2R + 2R\lambda - \theta_{A2}\right) < R$, violating the assumption $p_{A2} \ge R$. Examining the boundary solutions, we find that $p_{A2} = R$ is a local maximum. If $R-\theta_{A2} \le p_{A2} \le R$, then $\pi_{A2} = \frac{1}{\lambda R}\left(\theta_{A2}\lambda R - \frac{1}{2}\left[\theta_{A2} - \left(R - p_{A2}\right)\right]^2\right)\cdot p_{A2}$, and $p_{A2}^* = \frac{1}{3}\left(2R - 2\theta_{A2} + \sqrt{\left(R-\theta_{A2}\right)^2 + 6\lambda R\theta_{A2}}\right)$. It can be verified that $d^2\pi_{A2}/dp_{A2}^2\big|_{p_{A2}=p_{A2}^*} < 0$ and $R-\theta_{A2} \le p_{A2}^* \le R$. Comparing two local maximum points yields the global maximum $p_{A2} = p_{A2}^*$.

Now, consider the second scenario $R\lambda < \theta_{A2}$. We have $R-\theta_{A2} \le p_{A2} \le R(1+\lambda)-\theta_{A2}$. Following a similar argument as above, we know $p_{A2} < R-\theta_{A2}$ and $p_{A2} > R(1+\lambda)-\theta_{A2}$ are impossible. Solving the F.O.C. also yields $p_{A2} = p_{A2}^*$. *Q.E.D.*

Lemma 2: A vs. O with Lock-in

Solving $\begin{cases} p_{A2} = \frac{1}{3}\left(2R - 2\theta_{A2} + \sqrt{\left(R-\theta_{A2}\right)^2 + 6\lambda R\theta_{A2}}\right) \\ \theta_{A2} = \frac{1}{4}\left(2 - p_{A1} - p_{A2}\right) \end{cases}$ yields

$$p_{A2} = \frac{1}{33}\left[7(p_{A1}-2)+4R(7-\lambda)+4\sqrt{4+8R(5\lambda-2)+R^2(\lambda^2-14\lambda+16)-4(5R\lambda-2R+1)p_{A1}+p_{A1}^2}\right] \quad (5)$$

Thus, platform A's second-period price and profit can be expressed as $p_{A2}(p_{A1})$ and $\pi_{A2}(p_{A1})$.

The first-period profit can be written as

$$\pi_{A1}(p_{A1}) = \tfrac{1}{\lambda R}\left[\tfrac{1}{2}(R'-R)(\theta_{A1}-\theta_{A2})+R\lambda\theta_{A2}\right]p_{A1},$$

where $\theta_{A1} = \tfrac{1}{3}(2-R-p_{A1})$, $\theta_{A2} = \tfrac{1}{4}(2-p_{A1}-p_{A2})$, $p_{A2} = p_{A2}(p_{A1})$, and

R' solves $\tfrac{1}{3}(2-R'-p_{A1}) = \tfrac{1}{4}(2-p_{A1}-p_{A2})$.

Denote $\pi_A = \pi_{A1}(p_{A1})+\pi_{A2}(p_{A1})$. Using $0 \le \theta_{A2} \le 1$ and $R-1 \le p_{A2} \le R$, we have $-2-R \le p_{A1} \le 3-R$. Substituting $p_{A1} = t-R$ into $d\pi_A/dp_{A1} = 0$ and noting that

$$\left.\sqrt{4+16R(R-1)+40R\lambda-14R^2\lambda+R^2\lambda^2-(R-t)(7R-4-20R\lambda+t)}\right|_{R\to\infty} = R(3+\lambda)-a,$$

where $a = (t-2)(10\lambda-3)/(\lambda+3)$, we have $\left(d\pi_A/dp_{A1}|_{R\to\infty}\right) = 2\left[15+\lambda-2(6+\lambda)t\right]\Big/\left[3(3+\lambda)^2\right] = 0$.

Thus, $p_{A1}^* = (15+\lambda)/\left[2(6+\lambda)\right]-R$. It is easy to verify that $\left(d^2\pi_A/dp_{A1}^2|_{R\to\infty,p_{A1}=p_{A1}^*}\right) = -\left[4(6+\lambda)\right]\Big/\left[3(3+\lambda)^2\right] < 0$.

Using the result of p_{A1}^*, we can easily obtain p_{A2}, θ_{A2}, θ_{A1} and π_A. *Q.E.D.*

Proposition 1: The Lock-in Strategy Hurts the Proprietary Platform A

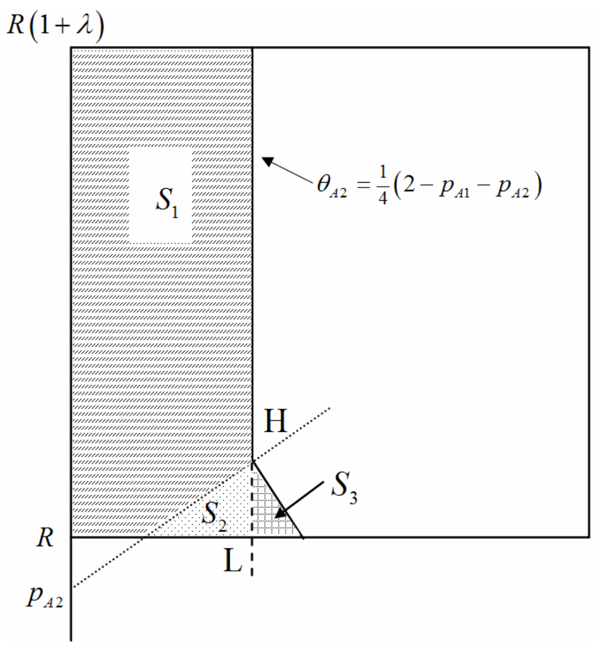

Figure 5: Platform Battle with Lock-in (A vs. O)

In the lock-in scenario, platform A's profit is $\pi_A = p_{A1}\left(S_1+S_2+S_3\right)/\left(\lambda R\right)+p_{A2}S_1/\left(\lambda R\right)$. Since $S_2 = 1/2\cdot\left(\overline{HL}\right)^2$, $S_3 = 1/2\cdot\overline{HL}\cdot 1/3\cdot\overline{HL}\le S_2$, and $p_{A1}<p_{A2}$, we have $p_{A1}\cdot S_3 < p_{A2}\cdot S_2 \Rightarrow \pi_A \le \left(p_{A1}+p_{A2}\right)\left(S_1+S_2\right)/\left(\lambda R\right)\equiv \pi_A^E$. Consider the scenario where there is no switching cost, platform A can get π_A^E if she charges $p_A^E = \left(p_{A1}+p_{A2}\right)/2$ in both periods. But p_A^E is not necessarily the optimal price in the scenario with zero switching cost. Therefore, $\pi_A \le \pi_A^E \le \pi_A^N$. *Q.E.D.*

Lemma 3: The Platform Battle between Two Proprietary Platforms

Substituting $\theta_{A2} = 1/2$ in (1) yields (3), so we focus on p_{i1}. Let $v = \lambda R$. First, we examine whether platform A has incentive to lower p_{A1} from the equilibrium price $p_{A1} = p_{B1} = p_1$ to $p_1 + dp_{A1}$ $\left(dp_{A1}\to 0, dp_{A1}\le 0\right)$. If it occurs, it creates three types of adopters: (1) those who can afford A and B in both periods; (2) those who can afford A or B in period 1 only; (3) those who can afford B in both periods but can afford A in period 1 only (see Figure 6).[9]

The marginal type 1 adopters satisfy: $2r-2\theta-\left(p_1+dp_{A1}\right)-\left(p_2+dp_{A2}\right) = 2r-2\left(1-\theta\right)-p_1-\left(p_2+dp_{B2}\right)$, or $\theta = \frac{1}{2}+d\theta_{A2}$, where $d\theta_{A2} = \frac{1}{4}\left(dp_{B2}-dp_{A1}-dp_{A2}\right)$. The marginal type 2 adopters satisfy: $r-\theta-\left(p_1+dp_{A1}\right) = r-\left(1-\theta\right)-p_1$, or $\theta = \frac{1}{2}+d\theta_{A1}$, where $d\theta_{A1} = -\frac{1}{2}dp_{A1}$. Lastly, the marginal type 3 adopters satisfy: $r-\theta-\left(p_1+dp_{A1}\right) = 2r-2\left(1-\theta\right)-p_1-\left(p_2+dp_{B2}\right)$, or $\theta = \frac{1}{3}\left(2-r-dp_{A1}+dp_{B2}\right)$. It can be shown that this line connects $\theta = \frac{1}{2}+d\theta_{A2}$ and $\theta = \frac{1}{2}+d\theta_{A1}$.

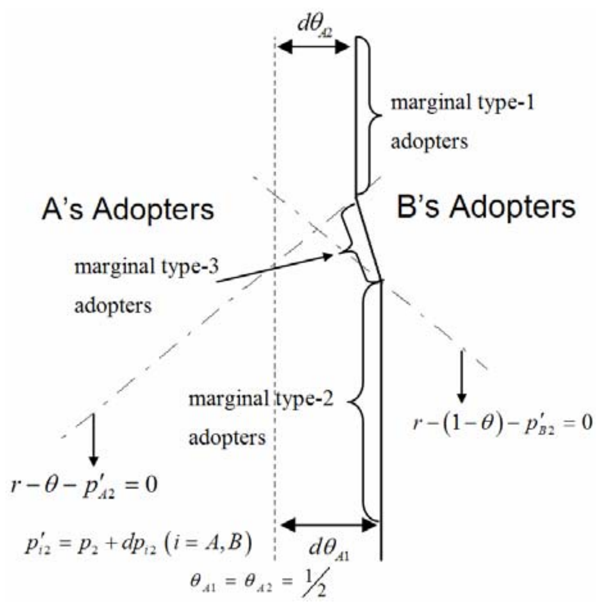

Figure 6: Three Types of Adopters

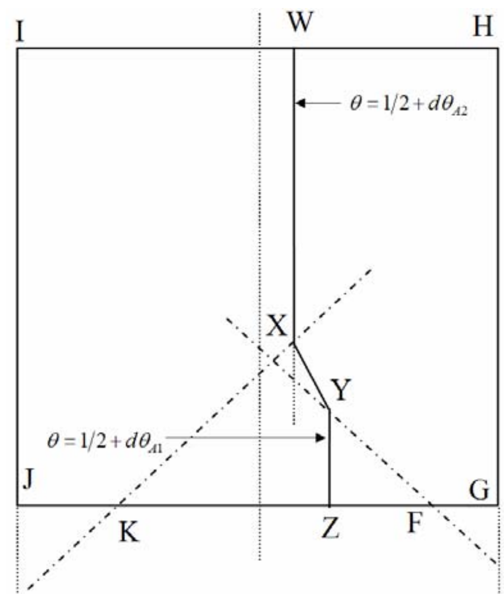

Figure 7: A & B's Market Share in Period 2

[9] It can be verified that if $dp_{A1}\to 0$, then the interception of $r-\theta-p'_{A2}=0$ and $\theta = 1/2+d\theta_2$ is higher than the interception of $r-\left(1-\theta\right)-p'_{B2}=0$ and $\theta=1/2+d\theta_2$. Thus, there are no such adopters who can afford A in both periods but can afford B in period 1 only.

Let $\alpha = dp_{A2}/d\theta_{A2}$, and $\beta = dp_{B2}/d\theta_{A2}$. Using (1), we get $\alpha = (1-2R+6v)/(3w) - 2/3$, where $v = \lambda R$, and $w = \sqrt{(2R-1)^2 + 12v}$. We know $\pi'_{B2} = S_{WXYFGHW} \cdot p'_{B2}/v$ (see Figure 7) and $d\pi'_{B2}/dp_{B2}|_{p_{B2}=p'_{B2}} = 0$. Solving them for p'_{B2} and noting that $d\theta_{A1} = \frac{1}{2}(4+\alpha-\beta)d\theta_{A2}$, we have $\beta = \frac{2(90v+7)+8R(7R+3v-7)+(26R-30v-13)w}{3w(4R-2+7w)}$.

Given α and β, $d\theta_{A2} = \frac{1}{4}(dp_{B2} - dp_{A1} - dp_{A2}) \Rightarrow d\theta_{A2} = -dp_{A1}/(4+\alpha-\beta)$,

$d\theta_{A1} = -dp_{A1}/2$, $dp_{A2} = -\alpha \cdot dp_{A1}/(4+\alpha-\beta)$, $dp_{B2} = -\beta \cdot dp_{A1}/(4+\alpha-\beta)$. Substituting these results and (3) in $d\pi_A = d\pi_{A1} + d\pi_{A2}$ yields $d\pi_A(dp_{A1}, p_{A1})$. Solving $d\pi_A/dp_{A1}|_{dp_{A1}\to 0} = 0$ for p_{A1} yields (4). Using a similar argument, we may conclude that platform A has no incentive to increase p_{A1} (that is, $dp_{A1} > 0$) when p_{A1} satisfies (4). It is straightforward to verify that the second-order condition holds. Lastly, we can obtain the results for $R \to \infty$ by using the similar derivation in the proof of Lemma 3. *Q.E.D.*

Proposition 2: The Platform Battle between Two Proprietary Platforms

It can be shown that π_A is a non-decreasing function of λ (see Figure 9 in Appendix A).[10] Since $\pi_A|_{\lambda\to 0} = 0.75 < \pi_A^N = 1$, the lock-in strategy would always hurt both platform providers if $\pi_A|_{\lambda=1} < 1$. Solving $(\pi_A|_{\lambda=1}) - \pi_N^A = 0$ for R yields $\hat{R} = 3.472$. It means as long as $R > \hat{R}$, there always exists a $\hat{\lambda}$ such that $\pi_A < \pi_A^N$ when $\lambda < \hat{\lambda}$, and $\pi_A > \pi_A^N$ when $\lambda > \hat{\lambda}$.

Further, if $R \to \infty$, we have $\pi_A = \pi_B = 3(2+\lambda)/8$. Comparing with $\pi_A^N = \pi_B^N = 1$, we have $\hat{\lambda} = 2/3$ for $R \to \infty$.

Comparative Statistics

We use the results obtained in the proof of Lemma 3 directly. $\pi_{A2} = \frac{1}{\lambda R}\left[\theta_{A2}\lambda R - \frac{1}{2}(\theta_{A2} - R + p_{A2})^2\right] \cdot p_{A2}$. Note that $p_{A2} = \frac{1}{6}\left[4R - 2 + \sqrt{(2R-1)^2 + 12R\lambda}\right]$ and $\theta_{A2} = 1/2$ at the equilibrium, $\lim_{R\to\infty}(d\pi_{A2}/d\theta_{A2} - R) = (\lambda/2) - 1$.

$dp_{A2}/d\theta_{A2} = \alpha = (1-2R+6v)/(3w) - 2/3$, where $w = \sqrt{(2R-1)^2 + 12v}$ and $v = \lambda R$. It is easy to obtain $\lim_{R\to\infty} \alpha = \lambda - 1$.

Note that $d\theta_{A2} = \frac{1}{4}(dp_{B2} - dp_{A1} - dp_{A2})$, $\alpha = dp_{A2}/d\theta_{A2}$, and $\beta = dp_{B2}/d\theta_{A2}$, we get $d\theta_{A2}/dp_{A1} = -1/(4+\alpha-\beta)$. Lastly $\lim_{R\to\infty} -1/(4+\alpha-\beta) = 3/(6+4\lambda)$.

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[10] The sketch of proof is as follows. First, $\pi_A = \pi_{A1} + \pi_{A2} = 1/2 \cdot p_{A1} + \pi_{A2}$ .We can show that $dp_{A1}/d\lambda \ge 0$ and $d\pi_{A2}/d\lambda \ge 0$. Consider $dp_{A1}/d\lambda$, which can be rewritten as $dp_{A1}/d\lambda = K_1(R,\lambda) \cdot K_2(R,\lambda)$ where $K_1(R,\lambda) > 0$. It is easy to get $K_2(R,\lambda)|_{\lambda\to 0} = 0$, and $dK_2(R,\lambda)/d\lambda|_{\lambda\to 0} = 0$. Consider $d^2K_2(R,\lambda)/d\lambda^2$, we can show that it is always no less than zero as long as $R > 2.6$. Thus, $dp_{A1}/d\lambda \ge 0$ when $R > 2.6$. Numerical experiments show that $dp_{A1}/d\lambda \ge 0$ also hold for $1 \le R \le 2.6$. Using a similar argument, we can prove that $d\pi_{A2}/d\lambda \ge 0$. The detailed proofs are available upon request.

Proposition 3: Myopic Adopters

1) A vs. O with Myopic Adopters

When adopters are myopic, they only consider the first-period payoff. Thus, the marginal adopters $\left(r,\theta_{A1}\right)$ who are indifferent from adopting A and adopting O in period 1 satisfy:

$$r - p_{A1} - \theta_{A1} = r - \left(1-\theta_{A1}\right), \quad \text{or} \quad \theta_{A1} = \left(1-p_{A1}\right)/2 .$$

Since $\theta_{A1} \in \left[0,1\right]$, it follows that $p_{A1} \in \left[-1,1\right]$. Further, $\pi_{A1} = p_{A1}\theta_{A1} = p_{A1}\left(1-p_{A1}\right)/2$, $d\pi_{A1}/dp_{A1} = 1/2 - p_{A1}$, and $d\theta_{A1}/dp_{A1} = -1/2$. In the second period, adopters $\left(r,\theta\right)$ with $\left\{\theta \le \theta_{A2} = \theta_{A1}, r - p_{A2} - \theta_{A2} \ge 0\right\}$ continue to use platform A while other locked-in adopters are priced out of the market by platform A. If R is sufficiently large, we have $d\pi_{A2}/d\theta_{A2} \approx R - \theta_{A2}\left(2-\lambda\right)$ using $\pi_{A2} = \frac{1}{\lambda R}\left(\theta_{A2}\lambda R - \frac{1}{2}\left[\theta_{A2} - \left(R - p_{A2}\right)\right]^2\right)\cdot p_{A2}$ and (1). Substituting these results and $\theta_{A2} = \theta_{A1}$ in

$$d\pi_{A}/dp_{A1} = \left(d\pi_{A1}/dp_{A1}\right) + \left(d\pi_{A2}/d\theta_{A2}\right)\cdot\left(d\theta_{A2}/dp_{A1}\right)$$

yields $d\pi_{A}/dp_{A1} = -R/2 + C$, where $C = \left[1 - 2p_{A1} + \left(2-\lambda\right)\theta_{A1}\right]/2$.

Noting that $p_{A1} \in \left[-1,1\right]$, $\theta_{A1} \in \left[0,1\right]$, and $\lambda \in \left[0,1\right]$, C is bounded in $\left[-0.5, 2.5\right]$. Thus, $d\pi_{A}/dp_{A1} < 0$ in $p_{A1} \in \left[-1,1\right]$, implying that $p^*_{A1} = -1$ (platform A captures the whole market in period 1). Therefore, $\pi_A = -1 + \pi_{A2} \approx -1 + R + \left(2k + \lambda - 2\right)/2 \to \infty$. Apparently, platform A's provider gets a higher profit compared with the identical market where there is no switching costs. That is, platform A should lock-in adopters. Numerical experiments show that such conclusion also holds for small *R* (see Figure 10).

2) A vs. B with Myopic Adopters

Following a similar argument as above, it is straightforward to prove that if $p_{B1} \ge 0$ and *R* is sufficiently large, platform A would capture the whole market by charging $p_{A1} = p_{B1} - 1$, resulting in $\theta_{A1} = 1$ and $\pi_B = 0$. Thus, both p_{A1} and p_{B1} should be less than zero at the equilibrium, implying that no adopters are left out of the market in period 1. Since adopters are myopic, the marginal adopters $\left(r,\theta_{A1}\right)$ satisfy:

$$r - p_{A1} - \theta_{A1} = r - p_{B1} - \left(1-\theta_{A1}\right), \quad \text{and } \theta_{A1} = \theta_{A2}$$

It follows $d\pi_{A1}/dp_{A1} = \left(1 - 2p_{A1} + p_{B1}\right)/2$, and $d\theta_{A2}/dp_{A1} = -1/2$. Substituting these results and $d\pi_{A2}/d\theta_{A2} \approx R - \theta_{A2}\left(2-\lambda\right)$ into

$$d\pi_{A}/dp_{A1} = \left(d\pi_{A1}/dp_{A1}\right) + \left(d\pi_{A2}/d\theta_{A2}\right)\cdot\left(d\theta_{A2}/dp_{A1}\right) = 0$$

yields $p_{A1} = \left(1 - R + p_{B1} + 2\theta_{A2} - \lambda\theta_{A2}\right)/2$. It is easy to verify that $d^2\pi_A/dp^2_{A1} = -1 - \left(2-\lambda\right)/4 < 0$.

We focus on the symmetric equilibrium where $p^*_{A1} = p^*_{B1}$, and $\theta_{A1} = \theta_{A2} = 1/2$. Therefore,

$$p^*_{A1} = p^*_{B1} = 2 - R - \lambda/2, \text{ and thus } \pi_{A1} = \pi_{B1} = \left(2 - R - \lambda/2\right)/2 .$$

Using (1), we have $\pi_{A2} \approx \theta_{A2}R + \theta^2_{A2}\left(\lambda-2\right)/2$, and $\pi_{A2} = \pi_{B2} \approx R/2 + \left(\lambda-2\right)/8$ when $\theta_{A2} = 1/2$. Thus,

$$\pi_A = \pi_B = \left(6-\lambda\right)/8 < 1 .$$

Therefore, platform A and B's providers should not lock-in adopters regardless of the value of λ. Numerical experiments obtain the same result for small *R* (see Figure 11).

Numerical Experiments

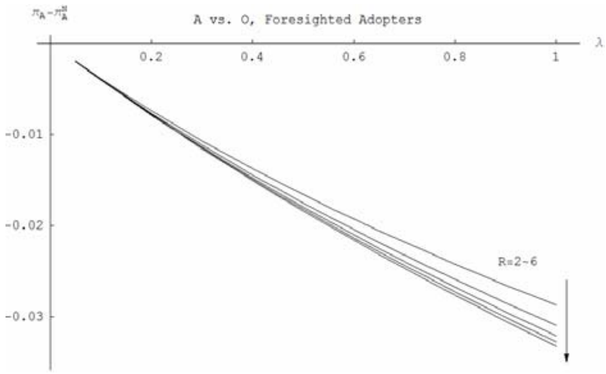

Figure 8: The Lock-in Strategy Hurts A

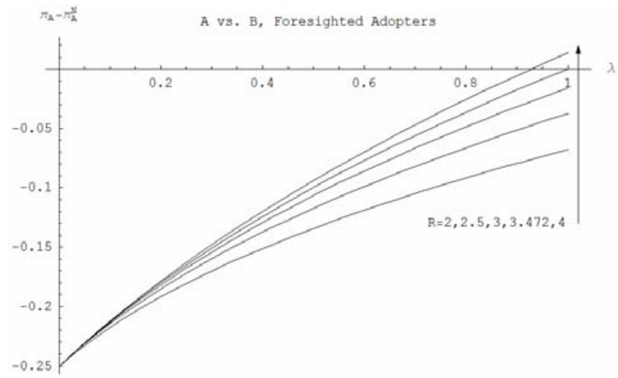

Figure 9: The Lock-in Strategy Always Hurts A & B if 2<= *R* < 3.472

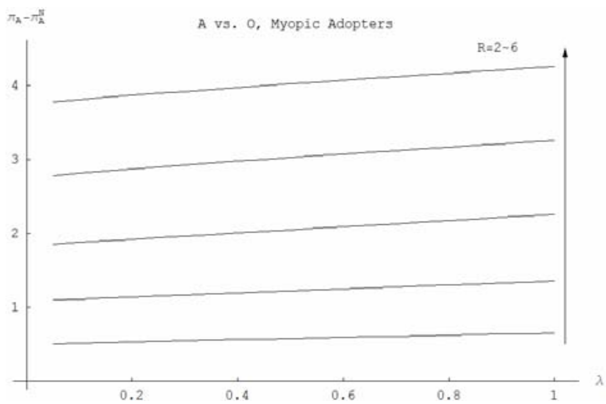

Figure 10: The Lock-in Strategy Benefits A

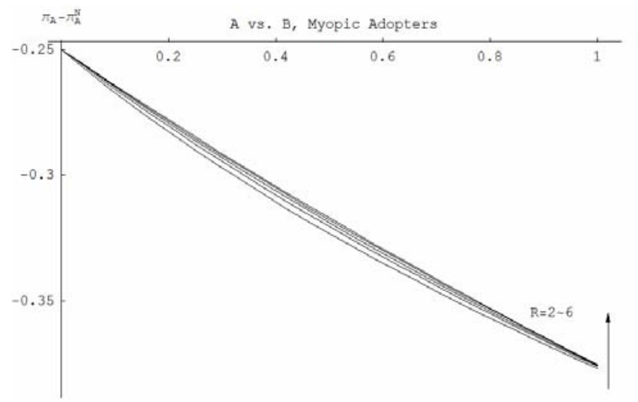

Figure 11: The Lock-in Strategy Always Hurts A & B

References

Bensaid, B., J. Lesne. "Dynamic Monopoly Pricing with Network Externalities," *International Journal of Industrial Organization* (14), 1996, pp.837-855.

Berinato, S. ".NET, Web Services, and the End of the Vendor Era," *CIO Magazine,* Nov 2005.

Caminal, R., C. Matutes. "Endogenous Switching Costs in a Duopoly Model," *International Journal of Industrial Organization* (8:3), 1990, pp.353-373.

Chen, P. Y., L. M. Hitt. "Measuring Switching Costs and the Determinants of Customer Retention in Internet-enabled Businesses: a Study of the Online Brokerage Industry," *Information Systems Research* (13:3), 2002, pp.255-274.

Farrell, J., P. Klemperer. "Coordination and Lock-In: Competition with Switching Costs and Network Effects," *Working Paper*, 2004, http://www.paulklemperer.org.

Farrell, J., C. Shapiro. "Optimal Contracts with Lock-in," *The American Economic Review* (79:1), 1989, pp.51-68.

Forrester. "IT view research report: Java And .NET Have Yet to Kill All Other Platforms: Adoption Trends for .NET and Java Remain Stable," 2005, http://www.forrester.com.

Frost, J. J. "Some Economic & Legal Aspects of Open Source Software," 2005, *Working Paper*, *University of Washington*.

Fuller, T. "How Microsoft Warded Off Rival," *New York Times*, May.15.2003.

Gartner "Research Note: J2EE and .NET Will Vie for E-business Development Efforts," 2003, http://gartner.metrostate.edu/research/114600/114609/114609.pdf

IBM "White Paper: IBM J2EE Middleware Platform vs. the Microsoft .NET Platform," 2004, http://www-1.ibm.com/linux/files/middleware_final7.pdf

Katz, M.L., C. Shapiro. "Network Externalities, Competition and Compatibility," *The American Economic Review* (75:3), 1985, pp.424-440.

Kim, B., M. Shi, K. Srinivasan. "Reward Programs and Tacit Collusion,"*Marketing Science* (20:2), 2001, pp.99-120.

Klemperer, P. "Markets with Consumer Switching Costs," *The Quarterly Journal of Economics* (102:2), 1987(a), pp.375-394.

Klemperer, P. "The Competitiveness of Markets with Switching Costs," *The RAND Journal of Economics* (18:1), 1987(b), pp.138-150.

Klemperer, P. "Competition When Consumers Have Switching Costs: an Overview with Applications to Industrial Organization, Macroeconomics, and International Trade," *The Review of Economic Studies* (62:4), 1995, pp.515-539.

Kucharik, A. "Vendor Lock-in," 2003, http://searchopensource.techtarget.com/qna/0,289202,sid39_gci913129,00.html

Longworth, D. "Grid Lock-in on Route to SOA," 2004, http://www.looselycoupled.com.

Mariñoso, B. G. "Technological Incompatibility, Endogenous Switching Costs and Lock-in," *The Journal of Industrial Economics* (49:3), 2001, pp.281-298.

Marson, I. Special Issue to CNET: Open Source and Developing Nations. *CNET.com*, Nov.14.2005.

Microsoft "White paper: Application Interoperability: Microsoft .NET and J2EE," 2004, http://www.microsoft.com

Microsoft "Microsoft Offers Office Document Formats to Ecma International for Open Standardization," 2005, http://www.microsoft.com/presspass/press/2005/nov05/11-21EcmaPR.mspx

Miller, E. "DRM and Lock-in: Apple vs. Microsoft," June.10.2005, http://importance.corante.com/archives/2005/06/10/drm_and_lockin_apple_vs_microsoft.php

Mustonen, M. "Copyleft—the Economics of Linux and Other Open Source Software," *Information Economics and Policy* (15:1), 2002, pp.99-121.

Lerner, J., J. Tirole. "Some Simple Economics of Open Source," *The Journal of Industrial Economics* (50:2), 2002, pp.197-234.

Lohr, S. "Microsoft Putting Its Muscle Behind Web Programming Tools," *New York Times*. Feb.13.2002.

Rochet, J., J. Tirole. "Two-sided Markets: an Overview," *Working Paper*, 2004, Institut d'Économie Industrielle (IDEI).

Shilony, Y. "Mixed pricing in oligopoly," *Journal of Economic Theory* (14), 1977, pp.373-388.

The Register. "Writing History with Microsoft's Office Lock-in: No XML please, We're Arbitrary, " 2003, http://www.theregister.co.uk/2003/04/25/writing_history_with_microsofts_office

Tyagi, R.K. "Technological Advances, Transaction Costs, and Consumer Welfare," *Marketing Science* (23:3), 2004, pp.335-344.

Vawter, C., E. Roman. "J2EE vs. Microsoft .NET: a Comparison of Building XML-based Web Services. The Middleware Company's White Paper," 2001, http://www.middleware-company.com/

Viswanathan, S. "Competing Across Technology-differentiated Channels: the Impact of Network Externalities and Switching Costs," *Management Science* (51:3), 2005, pp.483-496.

Von Weizsäcker, C. "The Costs of Substitution," *Econometrica* (52:5), 1984, pp.1085-1116.

Zhu, K. "Information Transparency of Business-to-Business Electronic Markets: A Game-Theoretic Analysis," *Management Science* (50:5), 2004, pp. 670-685.

Zhu, K., J. Weyant. "Strategic Decisions of New Technology Adoption under Asymmetric Information," *Decision Sciences* (34:4), 2003, pp. 643-675.