Tying, Compatibility and Upgrades*

Chun-Hui Miao†

Abstract

According to the hypothesis of planned obsolescence, a durable goods monopolist has an excessive incentive to introduce new products that make old units obsolete, and this reduces its overall profitability. In this paper, I reconsider the above hypothesis in the context of system upgrades. I find that, when a new feature is competitively supplied, a monopoly system maker chooses to bundle its own feature into an upgrade that is only backward compatible, even though a commitment of not introducing the upgrade is available and socially optimal. My model provides a new rationale of bundling. Its relevance to the Microsoft antitrust cases is discussed. (JEL D40, L00, L40)

Keywords: Bundling, Compatibility, Durable Goods, Network Externalities, Planned Obsolescence, Upgrade.

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†Department of Economics, University of South Carolina, Columbia, SC 29208. miao@moore.sc.edu.

> When a model was settled upon then every improvement on that model should be interchangeable with the old model, so that a car should never get out of date. (Henry Ford, My Life and Work, Chapter III)

> Consumers clearly think the price/value proposition of a Windows upgrade is excellent. Millions have bought upgrades, even though their PCs would continue to operate perfectly with their original operating system. (Bill Gates, "Compete, Don't Delete", The Economist, 06/13/98)

Consider a monopoly system maker in a market that lasts two periods. In the first period the firm sells the first-generation of its system A, which is perfectly durable. In the second period the firm develops a new feature, B. It can either sell B as a separate product or sell an upgraded version ($A'B$) that integrates B. Which way is more profitable? In this paper, I show that when competing with an independent supplier of B, a system maker earns a higher profit by selling $A'B$ that is only backward compatible with A, even though selling B as a separate product is socially optimal.

Many durable goods producers frequently introduce upgrades that incorporate new features. Rather than offering a new feature as a separate product, firms often integrate it into an upgrade. The most prominent example is Microsoft Windows, whose bundling of Internet Explorer (IE) and Windows Media Player (WMP) has each been the subject of two landmark antitrust cases.[1]

Since many of the new features can be unbundled from the Windows operating system and each of them can be sold as an individual application, how does Microsoft gain an advantage by tying them to the purchase of a new system?[2] Certainly there are technological reasons why upgrades are delivered this way, especially if an upgrade is a complete overhaul of

[1] U.S. v. Microsoft, U.S. District Court for the District of Columbia, Civil Action No. 98–1232 (TPJ); E.U. Commission Case COMP/C-3/37.792 Microsoft.

[2] Anecdote evidence suggests that Microsoft intentionally cripples software programs so that they cannot be installed on old operating systems. In one instance, after removing one line of code that checks the version of Windows, users are able to install Windows Defender, a security software, onto Windows 2000 despite Microsoft's claim to the contrary. Brian Livingston, "Microsoft Turns Up The Heat On Windows 2000 Users", *Information Week*, Dec. 15, 2006.

the original system that cannot be accomplished by merely adding individual applications. The main contribution of this paper is to show that, even when technologically feasible, a monopoly system maker may choose not to offer new features separately from the system because tying allows the monopolist to exploit network externalities.[3]

I first examine the case in which a monopoly system maker[4] is also the only supplier of a new application and consumers differ in their willingnesses to pay for the application. When there are network effects between users of the same system, tying the application to the purchase of an upgrade that is only backward compatible increases sales, as even low-valuation consumers upgrade for fear of losing network benefits. However, forward-looking consumers will pay less for the original system thus lowering the monopolist's overall profitability. Therefore, a monopolist will commit not to introduce bundled upgrades.

I then turn to the case in which the monopoly system maker faces competition from an independent supplier in the application market. I find that a commitment to tying emerges as a profitable strategy. By integrating its application into a new system, the system maker turns the competition between two applications into a competition between two systems. This change intensifies the competition for market share, crucial in the presence of network externalities, and lowers the prices of applications thus allowing the system maker to charge a higher price for the original system. In other words, the system maker uses tying to engage in a price squeeze (Ordover, Sykes and Willig, 1985) and capture the surplus created by entry of the independent supplier. I find that this price squeeze strategy is most effective when the upgrade is backward compatible, but it lowers social welfare.

In both cases, tying entails (complete) incompatibility between the system maker's own application and its old system. This, coupled with incompatibility between the two systems,[5]

[3] Although my model is patterned after the software industry, it is equally applicable to durable hardware markets that exhibit consumption externalities. The many sources of consumption externalities are discussed by Katz and Shapiro (1985).

[4] I limit my attention to system markets that have a monopoly supplier. This choice appears reasonable given the central role played by network externalities in my model. Precisely because of network externalities, there is a natural tendency for these markets to be monopolized.

[5] Backward compatibility, as formally defined later in the paper, implies partial incompatibility.

changes a user's incentive to upgrade. Without tying, a user can buy a new application and keep the original system, hence all users remain on the same network and reap maximal network benefits. Tying induces users who have higher values for the application to migrate to a new system, thus depriving non-upgrading users of network benefits. This forces some users to buy the upgrade they don't need or buy the "wrong upgrade" if there are competing offers.

The traditional explanation for bundling is that it serves as an effective tool of price discrimination by a monopolist (Adams and Yellen, 1976; Schmalensee, 1982; McAfee, McMillan and Whinston, 1989; Bakos and Brynjolfsson, 1999), but this does not explain the use of pure bundling because mixed bundling gives the monopolist more freedom to price discriminate.

Following the seminal contribution by Whinston (1990), a number of papers (Choi and Stefanadis, 2001; Carlton and Waldman, 2002, 2006; Nalebuff, 2004) demonstrate the use of tying to extend a firm's monopoly power from one market to another.[6] However, they have had limited success in explaining Microsoft's bundling practices. Their models assume a physical tie that involves incompatibility with a rival's product, but Microsoft seems to have introduced relatively little incompatibility between its operating system and other applications (Whinston, 2001). These models also rely on the entry deterrence effect of tying, but its rivals were already active in their respective markets when Microsoft started the practice.[7] In fact, in the media player market, Microsoft's main rival, RealNetworks, is still in business; in the browser market, Microsoft faces a serious competitor, Mozilla Firefox, that emerged after the demise of Netscape. These facts, however, are consistent with my model, which suggests that tying can facilitate rent extraction by a monopoly system maker, who therefore has an incentive to accommodate entry. In this sense, my paper is close in spirit to Farrell and Katz (2000), who study a single producer of component A and several

[6] Other notable contributions include Choi (1996, 2004), who focuses on the long-term impact of tying on competition through innovation.

[7] In Nalebuff (2004), bundling can be profitable even if entry deterrence fails, but good A in his model is not essential to the use of good B. Therefore, his model fits well with Microsoft's bundling of Microsoft Office products but less so with its bundling applications into the operating system.

independent suppliers of a complementary component B. They show that the monopolist may have incentives to integrate into supply of component B so as to better extract efficiency rents in the competitive sector.

There is an extensive literature on competition between networks, but most of it focuses on the coordination-game aspect and considers network effects that are significant enough to generate a winner-takes-all outcome[8]. Surprisingly few models examine competitions with weak network externalities that lead to segmented networks, despite their wide existence. A recent paper by Grilo, Shy and Thisse (2001) studies a spatial duopoly model with consumption externalities. They find that, when the network effect is present but not too strong, product differentiation can sustain both firms but price competition is fiercer and results in lower prices. A similar result is obtained in my paper.

Finally, the idea that a durable goods monopolist with network externalities has too high an incentive to introduce new products that make current ones obsolete is related to the literature on planned obsolescence, originated by Waldman (1993, 1996).[9] He finds that a firm without commitment power may choose to sell a new incompatible version of its product even if it is inferior than the old version. Choi (1994) shows that a monopolist may choose to make a new product incompatible even though perfect compatibility is socially optimal. Ellison and Fudenberg (2000) analyze the consumers' coordination problem in detail and show that the monopoly outcome can be upgrades when the social optimum is incompatible networks. All these models assume within-generation consumer homogeneity so their welfare implications are different from mine. Most importantly, they do not address why a monopolist does not choose actions that commit itself not to introduce inefficient upgrades.

More closely related to my paper is the second analysis of Ellison and Fudenberg (2000), which attributes excessive upgrades to consumer heterogeneity: a monopolist's incentive to upgrade depends on the marginal consumer's valuation, but social welfare depends on

[8] See Farrell and Klemperer (2006) for a recent survey.

[9] See also Fishman and Rob, 2000; Kumar, 2002; Nahm, 2004.

the average consumer, therefore the monopolist's choice generally deviates from the social optimal. My paper extends their analysis in two important directions. First, my model highlights the role of tying and endogenizes the monopolist's choice of compatibility. Second, following their suggestion, I consider the role of competition in the application market. This allows me to show that a monopoly system maker may introduce inefficient upgrades, even if a commitment not to do so is available and socially optimal.

The remainder of this paper is organized as follows: Section I introduces the basic model. Section II examines the commitment problem of a monopoly supplier. Section III analyzes the choice of tying and compatibility by a monopoly system maker when it competes with an independent supplier of applications. Section IV considers several extensions. Section V relates the model to antitrust cases involving Microsoft's bundling practices. Section VI concludes. Any formal proofs omitted from the main text are contained in the appendix.

I. Basic Setup

I consider a two-period model, with periods $t = 1$ and $t = 2$ (see Figure 1). In period 1, a monopolist produces the first generation of the system (A). In period 2, the monopolist develops a new application; it can either introduce a system upgrade that integrates the new application ($A'B$) or sell the new application as a separate product (B).[10] If it chooses the first option, the monopolist can also manipulate the degree of compatibility between the upgrade $A'B$ and the old version A. I assume that both developing new applications and developing the upgrade involve fixed costs that are so small as not to affect the monopolist's upgrade decision.[11] In addition, I normalize the marginal costs of production to zero.

[10] I call B an application in order to provide concreteness, but B can refer to any new features or improvements that increase the system value. See footnote 13 for further discussion.

[11] A positive fixed cost will certainly reduce the monopolist's incentive to introduce an upgrade, but this effect is quite obvious. However, the fixed cost of developing a new application by a competitive supplier will play an important role in determining the optimal degree of compatibility when I consider the price squeeze effect of bundling in Section III.

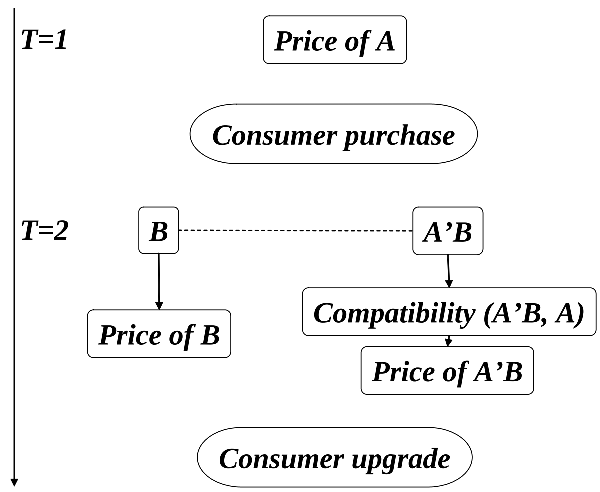

Figure 1: A Two-period Model

There is a continuum of consumers who enter the market at $t = 1$. Each consumer buys at most one unit of A in period 1 and one unit of either B or $A'B$ in period 2. I assume that consumers have quasi-linear preferences, so their utilities can be measured in monetary units.

To model network externalities, I assume that users of each version constitute a network and that a member of network i derives a network benefit of $N(\sum_{j=1}^{M} a_{ij}x_j)$ from M available networks, where x_j is the number of users on network j and a_{ij} is the network effect from network j to members of network i. I assume that $N(0) = 0$, $N' > 0$, $a_{ij} \in [0, 1]$, and $a_{ii} = 1$ for all i. I allow for partial compatibility, i.e., $a_{ij} < 1$ for some $j \neq i$. When a_{ij} takes the value of either 0 or 1, I obtain three special cases discussed in the literature:

- Full compatibility, $a_{ij} = 1$ for all i and j.
- Full incompatibility, $a_{ij} = 0$ for all $j \neq i$.
- One-way compatibility, $a_{ij} = 0$ and $a_{ji} = 1$, e.g., users of network i benefit only from other users of the same network, while users of network j get the full network benefits from users of both networks; if network j is a newer version of the system than network

i, then one-way compatibility implies backward compatibility discussed in Ellison and Fudenberg (2000).[12]

I assume that the "base value", independent of network externalities, of $A'B$ is the sum of two components, $v^{A'B} = v^A + u$, where v^A is the base value of A and u is the value of B. This specification means that, compared with B, the introduction of $A'B$ adds nothing but a channel through which A is made obsolete.[13] It is in this sense that an upgrade ($A \rightarrow A'$) is called inefficient. I further assume that v^A is the same across all consumers. This assumption guarantees that consumers' valuations of $A'B$ are perfectly correlated with their valuations of B. Besides simplifying the analysis, this assumption ensures that the incentive to bundle B cannot be attributed to price discrimination. I also suppose that v^A is so high that all consumers make purchases in the first period (no monopoly exclusion). It is easy to see that the absolute size of v^A as well as the first-period network benefits are immaterial to my analysis, so I normalize them to 0 in order to cut down the number of parameters of which we keep track. For the same reason, I suppose that there is no discount between periods for both consumers and firms.

Last, following Fudenberg and Tirole (1998), I assume that the monopolist can prevent consumers from delaying their purchases by offering an upgrade price only available to owners of the first-generation system, but the upgrade price is not set until period 2.[14]

[12] Lee (2006) also analyzes a monopolist's choice of compatibility between its successive generations of products, but he only considers the three special cases. In addition, his analysis is based on Choi (1994), which assumes within generation consumer homogeneity, so its welfare implication is different from mine.

[13] This assumption is without loss of generality. According to the goods-characteristics approach, products can be viewed as bundles of characteristics they embody (Lancaster 1966). Taking this approach, we can view B as simply a combination of features not included in A.

[14] The assumption that the monopolist cannot commit to future prices is not important in my analysis of the monopoly case (see the proof of Proposition 2) but is crucial in my analysis of the competitive case (See Section III.B for further discussion). A possible justification for this assumption is that such a commitment may reduce the monopolist's incentive to invest in R&D.

A. Compatibility

Before proceeding to my analysis, I pause a moment to discuss the link between tying and compatibility. Whinston (1990) argues that the effectiveness of tying largely depends on whether a system maker can make a commitment to tie through product design, in particular its choice of compatibility. This means that the tying decision, at its core, is a choice of (in)compatibility, one between the new application, B, and the original system, A. Note that this is different from the choice of compatibility between the two systems, $A'B$ and A : while the former necessitates a competition between the two systems, the latter regulates the intensity of that competition. At the same time, both can potentially, and indeed do in this paper, lead to incompatibility between a system maker's own products. Interestingly, the following analysis also shows that a system maker has a strong incentive to achieve compatibility between its system, A or $A'B$, and a rival's application, B'. This is a distinctive feature that separates my analysis from the existing literature, in which tying is always accomplished by introducing incompatibility with rivals' products.

II. Monopoly Pricing

In this section I show that, when consumers differ in their willingness to pay for B, a monopolist increases its second-period profit by tying B to the purchase of a system upgrade that is only backward compatible. This, however, lowers the monopolist's overall profitability, therefore it has an incentive to make a commitment not to tie. To model consumer heterogeneity, I assume that their reservation prices of B are represented by the distribution $F(u)$, strictly increasing with continuous density on the closed interval $[a, b]$.

A. The Second Period

At $t = 2$, if the monopolist sells B, then all users will keep the original system A and stay on the same network; a consumer of type u obtains a utility of $N(1)$ from continued use of

A and obtains $u + N(1)$ from adding B. But if the monopolist sells $A'B$, then there will be two networks of users. Let users of $A'B$ be network 1 and those of A be network 2; a consumer of type u obtains a utility of $N(\sum_{j=1}^{2} a_{2j}x_j)$ from continued use of A and obtains $u + N(\sum_{j=1}^{2} a_{1j}x_j)$ from upgrading to $A'B$.[15]

Because of the "coordination-game" aspect of network effects, it is possible that multiple equilibria exist. Moreover, consumers with different valuations may not have the same ordering of the possible equilibria, so one cannot use a Pareto criterion to select between the equilibria. Following Ellison and Fudenberg (2000), I assume that network effects are so small compared to other factors that the upgrade price leads to a unique equilibrium allocation, in which only users who value $A'B$ above some u^* choose to upgrade.

The monopolist's problem involves two choices: tying and compatibility, but only the latter is pivotal according to the following equivalence result.[16]

Lemma 1 *Selling B is equivalent to selling $A'B$ that is fully compatible with A.*

Proof. Obvious. ■

If $A'B$ is fully compatible with A, then consumers receive the same network benefits from using either version, so their upgrade decision will be purely driven by their valuations of B; whether B is tied makes no difference. Hence we can focus on the monopolist's choice of compatibility while taking its use of tying as given. If the solution entails full compatibility, then it implies unbundling as another solution. Lemma 1 not only helps streamline the exposition, but also shows that tying is an effective strategy only if the system maker can exploit network externalities by manipulating the degree of compatibility between its own systems.

Proposition 1 *The monopolist maximizes its second-period profit by selling $A'B$ that is only backward compatible, i.e., $a_{12} = 1$ and $a_{21} = 0$.*

[15] This corresponds to the "additive specification" in Ellison and Fudenberg (2000).

[16] This equivalence result breaks down if there are new system buyers in the second period, a case that I discuss in an extension of the model.

Proof. Suppose that the monopolist sells $A'B$. Without upgrading, a user gets $N\{F(u) + a_{21}[1-F(u)]\}$; after upgrading, one gets $u-p+N\{a_{12}F(u)+[1-F(u)]\}$, where p is the price of upgrade. Hence we must have $p = N\{a_{12}F(u^*)+[1-F(u^*)]\}-N\{F(u^*)+a_{21}[1-F(u^*)]\}+u^*$ and $\pi|_{t=2} = \max_u(N\{a_{12}F(u) + [1 - F(u)]\} - N\{F(u) + a_{21}[1 - F(u)]\} + u)[1 - F(u)]$. Applying the envelope theorem, we get $\frac{\partial}{\partial a_{21}}\pi|_{t=2} = -[1 - F(u^*)]^2 N' < 0$ and $\frac{\partial}{\partial a_{12}}\pi|_{t=2} = F(u^*)[1-F(u^*)]N' > 0$. Therefore, a choice of $a_{12} = 1$ and $a_{21} = 0$ (backward compatibility) maximizes $\pi|_{t=2}$. We can also rule out selling B alone based on Lemma 1. ■

The system maker faces a classic time inconsistency problem: once old units are sold, then a durable goods monopolist has a strong incentive to retire the old units in order to generate new sales. In my model, the system maker pushes users to abandon the original system by exploiting network externalities and consumer heterogeneity. Due to network externalities, the value of a system depends on the number of users. The upgrading decision of users who have high values for the new application imposes a negative externality on low valuation users, some of whom are "forced" to upgrade because it is too costly to be left behind (Dixit 2003). As a result, the original system is made obsolete even though it is perfectly durable. My model, however, does not require the existence of new consumers, as is typically assumed in existing models of planned obsolescence.

Example 1 *Suppose $u \sim U\ [0,1]$ and $N(x) = x/3$. If B is sold as a separate product, then half of the consumers buy it and the monopolist earns a profit of $1/4$. If B is bundled into a backward compatible upgrade $A'B$, then $3/4$ of the consumers upgrade and the monopolist's profit is $3/8$, a 50% increase. In fact, even introducing a fully incompatible upgrade increases the monopoly profit to $1/3$.*

Corollary 1 *The number of users who upgrade decreases with a_{21} if $N'' \leq 0$.*

Proof. First note that $\frac{\partial^2}{\partial u \partial a_{21}}\pi|_{t=2} = 2[1 - F(u)]N'\{F(u) + a_{21}[1 - F(u)]\} - (1 - a_{21})[1 - F(u)]^2 N''\{F(u) + a_{21}[1 - F(u)]\}$. This is positive if $N'' \leq 0$. Since $\text{sign}\frac{\partial u^*}{\partial a_{21}} = \text{sign}\frac{\partial^2 \pi(u^*)}{\partial u \partial a_{21}}$, we have $\frac{\partial}{\partial a_{21}}[1 - F(u^*)] < 0$. ■

B. The First Period

The time inconsistency problem faced by the monopolist implies that the policy optimal in the present may not be optimal in the future. Indeed, the introduction of a backward compatible upgrade reduces a non-upgrading users' network benefits and their willingness to pay for the original system, thus lowering the monopolist's total profits. Therefore,

Proposition 2 *To maximize total profits, the monopolist commits to either selling B alone or selling $A'B$ that is fully compatible with A.*

Proof. First, I show that full compatibility maximizes its total profits if the monopolist can commit to an upgrade price. With tying, a non-upgrading consumer obtains a network benefit of $N\{F(u^*) + a_{21}[1 - F(u^*)]$ in period 2, so the monopolist's total profits are $\pi = \max_u(N\{a_{12}F(u) + [1 - F(u)]\} - N\{F(u) + a_{21}[1 - F(u)]\} + u)[1 - F(u)] + N\{F(u) + a_{21}[1 - F(u)]\} = \max_u N\{a_{12}F(u) + [1 - F(u)]\}[1 - F(u)] + F(u)N\{F(u) + a_{21}[1 - F(u)]\} + u[1 - F(u)]$. By the envelope theorem, $\frac{\partial \pi}{\partial a_{12}} = \frac{\partial \pi}{\partial a_{21}} = F(u^*)[1 - F(u^*)]N' > 0$. Therefore, $a^*_{12} = a^*_{21} = 1$ (full compatibility) maximizes the monopoly profits.

Comparing $\pi|_{t=2}$ and π when $a_{12} = a_{21} = 1$, we can see that they differ by a constant $N(1)$. This means that any upgrade price that maximizes $\pi|_{t=2}$ also maximizes π. Therefore, by committing to full compatibility, the monopolist can obtain the maximal profit without necessarily committing to an upgrade price.

Last, by Lemma 1, selling B alone also achieves the full compatibility outcome. ■

Since a monopolist internalizes consumers' loss of network benefits, it will commit not to introduce frequent upgrades. This is by now a standard result. Nevertheless, contrary to prior research, in my model such a commitment is not necessarily welfare improving, as shown below.

C. Welfare

It is clear that marginal cost pricing achieves the first-best, under which all users upgrade so the choices of tying and compatibility do not matter. Given the focus of this paper, however, I examine the welfare implication of tying and compatibility under monopoly pricing.

First, it should be noted that the welfare implication is not the same across all users: non-upgrading users prefer full compatibility because it offers them greater network benefits, but upgrading users pay a higher price under full compatibility.

Second, while full compatibility maximizes network benefits, it reduces the number of upgrading users thereby increasing the degree of monopoly exclusion. The overall effect on welfare is ambiguous.

The total surplus is $TS = \int_{u^*}^{b} uf(u)dx + [1-F(u)]N\{a_{12}F(u)+[1-F(u)]\}+F(u)N\{F(u)+a_{21}[1-F(u)]\} = \pi(u^*) + \int_{u^*}^{b}(u-u^*)f(u)du$, where $u^* = \arg\max_u \pi(u)$. Hence, $\frac{\partial}{\partial a_{21}}TS = [1-F(u^*)][N'F(u^*) - \frac{\partial u^*}{\partial a_{21}}]$. By Corollary 1, $\frac{\partial u^*}{\partial a_{21}} > 0$. Thus, the total surplus may increase or decrease with a_{21} depending upon the parameter values.

III. A Competitive Supplier

In the monopoly case, a system maker lowers its own profitability with its frequent upgrades and thus has an incentive to choose actions that constrain its own ability to introduce upgrades (Waldman, 2003). Since firms like Microsoft do not seem to be taking any such actions, it is perhaps worthwhile to examine their actions from a different perspective.

Now I turn to the case in which the system maker competes with an independent supplier in the application market. I consider the following game (see Figure 2): the system maker sells A in period 1 and sells B or $A'B$ in period 2; at the beginning of period 1, the system maker sets the price of A and announces its choices of tying and compatibility for a future upgrade; consumers then make purchases; at the beginning of period 2, an independent supplier can enter the market by spending F to develop a competing application, B', also

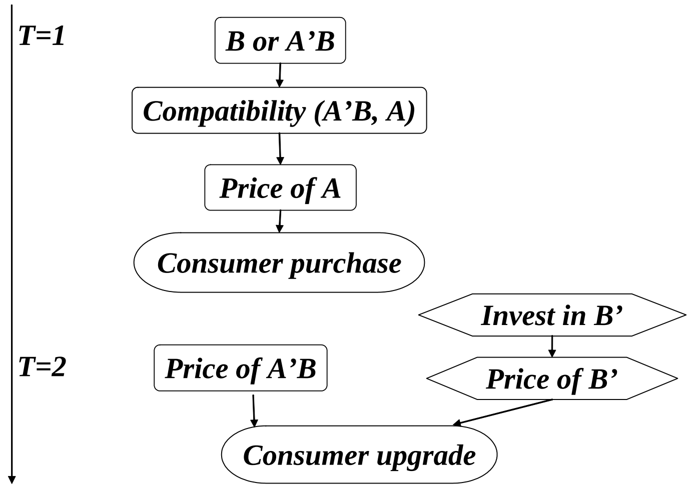

Figure 2: Competition with an Independent Supplier

produced at zero marginal cost. I assume that F is common knowledge and that $F < \frac{t}{2}$ so that entry is not blockaded.[17]

To study the competition in the application market, I consider a variation of the standard linear city model. I assume that consumers are uniformly distributed on a line $[0, 1]$ and that the two firms are located at the opposite ends of the line, with the system maker at 0 and the independent supplier at 1. Consumers have the same reservation price for an application offered by either firm, but a consumer incurs a transportation cost of td when buying from a firm located at a distance of d.[18]

I assume that transportation costs are small compared to a consumer's reservation price so the price competition game has a pure strategy equilibrium, in which the application market is covered. In addition, consumers derive network benefits from other users of the same system. For tractability, I assume that network benefits are linear in the size of a network, i.e., $N(x) = nx$. Again, I assume that network effects are sufficiently small, i.e., $n < t$, such that a unique equilibrium exists in which consumers in $[0, x]$ buy from the system

[17] The case in which F is private information is discussed in an extension.

[18] Just like the original Hotelling model, it is possible to generalize my results to non-uniform distributions and non-linear costs.

maker and consumers in $[x,1]$ buy from the independent supplier. Last, I assume that firms set prices simultaneously. The solution concept that I use is subgame perfect equilibrium.

It is easy to see that Lemma 1 still holds in the case studied here, so we focus on the system maker's choice of compatibility while taking its use of tying as given.

A. The Second Period

I start by solving the price competition subgame that takes place in the second period. Denote by p_m the price of $A'B$, p_e the price of B, $\pi_m|_{t=2}$ the system maker's second period profits, and π_e the independent supplier's (post entry) profits.

Proposition 3 *Full compatibility (incompatibility) maximizes (minimizes)* $\pi_m|_{t=2}$ *and* π_e.

Proof. In an interior solution, consumers located to the left of some x upgrade to $A'B$ (network 1) whereas others keep A (network 2) and buy B'. We must have $-tx - p_m + n[a_{12}(1-x)+x] = -t(1-x) - p_e + n[(1-x)+a_{21}x]$, hence the marginal consumer is located at $x = \frac{p_m - p_e - t + n(1-a_{12})}{n(2-a_{21}-a_{12})-2t}$ and $\pi_m|_{t=2} = \frac{p_m - p_e - t + n(1-a_{12})}{n(2-a_{21}-a_{12})-2t} p_m$. The system maker's FOC is $p_m - p_e - t + n(1-a_{12}) + p_m = 0$. Similarly, we can get $\pi_e = \frac{n(1-a_{21})-t-p_m+p_e}{n(2-a_{21}-a_{12})-2t} p_e$ and $n(1-a_{21}) - t - p_m + 2p_e = 0$. Solving, we obtain $p_e^* = \frac{n(-a_{21}+a_{12})}{3} + t - n(1-a_{21})$, $p_m^* = \frac{2n(-a_{21}+a_{12})}{3} + t - n(1-a_{21})$, $x^* = \frac{\frac{n(-a_{21}+a_{12})}{3} - t + n(1-a_{12})}{n(2-a_{21}-a_{12})-2t}$, $\pi_m|_{t=2} = \frac{1}{9}\frac{[3t-[n(3-a_{21}-2a_{12})]]^2}{2t-n(2-a_{21}-a_{12})}$, and $\pi_e = \frac{1}{9}\frac{(3t-(n(3-2a_{21}-a_{12})))^2}{2t-n(2-a_{21}-a_{12})}$. Differentiating and noting that $t > n$, we get $\frac{\partial}{\partial a_{21}}\pi_m|_{t=2} = \frac{n}{9}\frac{(t-n+na_{21})(3t-3n+2na_{12}+na_{21})}{(2t-2n+na_{12}+na_{21})^2} > 0$, $\frac{\partial}{\partial a_{12}}\pi_m|_{t=2} = \frac{n}{9}\frac{(3t-3n+2na_{12}+na_{21})(5t-5n+2na_{12}+3na_{21})}{(2t-2n+na_{12}+na_{21})^2} > 0$, $\frac{\partial \pi_e}{\partial a_{21}} = \frac{n}{9}\frac{(5t-5n+2na_{21}+3na_{12})(3t-3n+2na_{21}+na_{12})n}{(2t-2n+na_{21}+na_{12})^2} > 0$ and $\frac{\partial \pi_e}{\partial a_{12}} = \frac{n}{9}\frac{(t-n+na_{21})(3t-3n+na_{21}+2na_{12})}{(2t-2n+na_{21}+na_{12})^2} > 0$. This means that both $\pi_m|_{t=2}$ and π_e are maximized (minimized) at $a_{21} = a_{12} = 1$ $(a_{21} = a_{12} = 0)$. ■

It is not difficult to see the intuition behind the result. When an upgrade is incompatible with the old system, competition between the two firms becomes a competition between two networks. Gaining an additional customer not only increases sales but also makes a firm's product more attractive to other users. Therefore, each firm has a strong incentive to cut price and increase its market share. This intensifies competition and lowers its profit.

Since full incompatibility minimizes the independent supplier's profits, it appears that the system maker may use it to deter entry into the application market. Interestingly, the analysis below shows that the system maker would rather accommodate entry and take advantage of its monopoly position in the system market to capture the additional surplus that its rival's presence generates (due to product differentiation).

B. The First Period

In the monopoly case, the system maker reverses its choices of tying and compatibility when it gains the ability to commit. Here again, the system maker faces a time inconsistency problem: in charging a high price for the application, it reduces a consumer's willingness to pay for the system. Therefore,

Proposition 4 *In the unique subgame perfect equilibrium, the system maker commits to selling $A'B$ that is only backward compatible and accommodates entry. More specifically,* $a_{21}^* = 1$ *and* $a_{12}^* = \max(0, a)$, *where* a *is the solution to* $\frac{1}{9}\frac{[3t-2n(1-a)]^2}{2t-n(1-a)} = F$.

Proof. If the independent supplier does not enter, then all users buy from the system maker, whose total profits are $u + n - t$.

If the independent supplier enters, then the marginal consumer's valuation of the original system is $u + (n-t)x^* - p_m^* + na_{12}(1-x^*)$. Since u is so high that the system maker sells the system to all consumers, its total profits are $\pi_m = u + (n-t)x^* - p_m^* + na_{12}(1-x^*) + \pi_m|_{t=2}$, where x^*, p_m^* and $\pi_m|_{t=2}$ are solved in the proof of Proposition 3. Differentiating, we get $\frac{\partial \pi_m}{\partial a_{12}} = \frac{n}{9}\frac{4n(t-n)(a_{12}+2a_{21})+6(t-n)^2+n^2(2a_{12}a_{21}+a_{12}^2+3a_{21}^2)}{(2t-2n+na_{12}+na_{21})^2} > 0$ and $\frac{\partial \pi_m}{\partial a_{21}} = -\frac{2n}{9}\frac{(3t-3n+2na_{12}+na_{21})(t-n+na_{21})}{(2t-2n+na_{12}+na_{21})^2} < 0$. In addition, we have $\pi_m(a_{12} = a_{21} = 1) = u + n - t = \pi_m$(no entry). Therefore, entry benefits the system maker. Since a higher a_{12} increases both the independent supplier's and the system maker's profits, we must have $a_{12}^* = 1$. As for a_{21}, it should be set just high enough such that $\pi_e = \frac{1}{9}\frac{[3t-2n(1-a_{21})]^2}{2t-n(1-a_{21})} = F$ in order to allow entry or

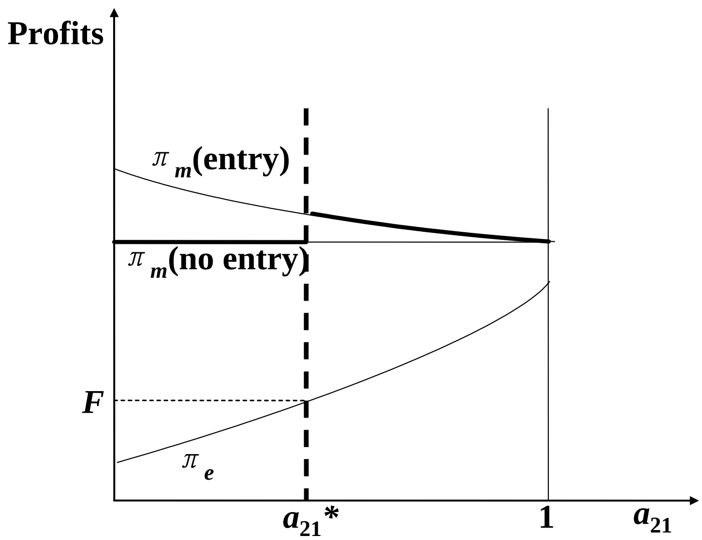

Figure 3: A system maker's total profits when there is a competitive supplier of applications and $a_{12} = 1$.

at 0 if $\frac{1}{9}\frac{(3t-2n)^2}{2t-n} > F$. This implies backward compatibility, where users of AB' receive only partial benefits from users of $A'B$. ∎

The trade-off faced by the system maker is illustrated in Figure 3. On one hand, for any given value of a_{12}, the system maker's total profits decrease with a_{21}; on the other hand, the independent supplier's post-entry profits increase with a_{21}, hence too low an a_{21} may discourage entry. At the same time, the system maker benefits from entry since $\pi_m(\text{entry}) > \pi_m(\text{no entry})$ for all values of a_{21}. Therefore, the optimal strategy for the system maker is to set a_{21} just high enough to cover the independent supplier's entry cost.[19]

By committing to a tie-in of the application with an upgrade that is only backward compatible, the system maker promises a tough fight with the independent supplier of applications upon its entry. This increases a consumer's willingness to pay for the original system and raises the system maker's overall profitability at its rival's expense. In other words, tying enhances the system maker's ability to engage in a price squeeze: by forcing

[19] It is worth noting that the exact form of backward compatibility derived in my model differs from the definition used in Ellison and Fudenberg (2000), according to which users of the old version gains zero network benefits from users of the new version.

the independent supplier to charge a lower price than it otherwise would, the system maker captures surplus created by the entry of the independent supplier.

Here, tying is profitable precisely because it gives the system maker the leverage to change the rules of the game in the application market. If the system maker sells its application as a separate product, then the competition in the application market is just a competition between differentiated products; but if the system maker ties the sale of its application to a new system, then users who prefer the independent supplier will keep the old system whereas users who prefer the system maker will have to upgrade to a new system and move to a different network. Basically, tying turns the competition between two applications into a competition between two network systems, thus allowing the system maker to take advantage of its control over the system design and its ability to manipulate the degree of compatibility.

The above result contrasts with that of Whinston (1990), who shows under a wide variety of conditions that a monopolist cannot gain from tying complementary products used in fixed proportions. The key difference is the inter-temporal nature of my model. Note that tying is not profitable if the system maker can commit to a low upgrade price and use it to engage in a perfect price squeeze. In Whinston's model, a commitment in price is readily available because components of a system are offered all at once. In my model, however, an upgrade is offered after the system purchase and a commitment in the upgrade price may not be feasible.[20] Therefore, a system maker has to resort to tying, which partially restores its ability to engage in a price squeeze.

My model is also distinct from existing foreclosure models in the role of tying: instead of limiting consumers' choices in the application market, tying is used by a system maker in my model to limit consumers' choices in the system market among its own products. Note that consumers upgrade to $A'B$ because B is not available for users of the original system A, even though consumers are free to add B' from the independent supplier onto any system.

[20] Carlton and Waldman (2006) also show that tying can be profitable if a monopoly system maker cannot commit to upgrade prices, but their emphasis is on application upgrades, not system upgrades. Their model predicts foreclosure, whereas mine predicts entry accommodation.

To put it another way, it's the abandonment of old systems, but not the integration with the new system or the exclusion of rival products, that makes the tie-in of applications so appealing to the system maker. This distinction implies that policy makers focusing on the physical integration of applications may have targeted the wrong subject, a point that I will return to later in this paper.

Corollary 2 *The system maker's total profits decreases with F.*

Proof. First, a increases with F; second, π_m decreases with $a_{21} = \max(0, a)$. Therefore, π_m (weakly) decreases with F. ■

Since the system maker can manipulate the degree of compatibility between its systems such that the independent supplier's post entry profits barely cover the entry cost, any efficiency gain by the independent supplier in the form of a lower fixed cost will be appropriated by the system maker. Therefore, the system maker may have an incentive to provide open standards in order to facilitate the development of third-party applications, while at the same time introducing incompatibility between its own systems. Interestingly, this seems to be consistent with Microsoft's past behavior.[21]

C. Welfare

Whereas the welfare implication of tying and compatibility is ambiguous in the monopoly case, it is unambiguous in the competitive case: tying the application into an upgrade that is backward compatible lowers welfare. This is due to the combination of two effects: first, partial compatibility reduces total network benefits; second, backward compatibility distorts some consumers' purchase decisions and increases their transportation costs. In fact,

Proposition 5 *Social welfare is maximized when $a_{12} = 1$ and $a_{21} = 1$.*

[21] "Windows is a piece of intellectual property whose 'facilities' are totally open to partners and competitors alike. Windows' programming interfaces are published free of charge, so millions of independent software developers can make use of its built-in facilities (eg, the user interface) in the applications they design." Bill Gates, "Compete, Don't Delete", The Economist, 06/13/98.

Proof. The total surplus is determined by network benefits and transportation costs. It can be written as $TS = x^* N\{F(x^*) + a_{12}[1 - F(x^*)]\} + (1 - x^*) N\{a_{21}F(x^*) + [1 - F(x^*)]\} - \int_0^{x^*} txf(x)dx - \int_{x^*}^1 t(1-x)f(x)dx$, where x^* is the location of the marginal user and $F(\cdot)$ is the CDF that represents the distribution of users on the line of $[0, 1]$. First, $TS \leq 1 - \int_0^{x^*} txf(x)dx - \int_{x^*}^1 t(1-x)f(x)dx \leq 1 - \int_0^{0.5} txf(x)dx - \int_{0.5}^1 t(1-x)f(x)dx$; second, if $a_{12} = 1$, $a_{21} = 1$, and if $f(x)$ is symmetric, then $x^* = 0.5$ so $TS = 1 - \int_0^{0.5} txf(x)dx - \int_{0.5}^1 t(1-x)f(x)dx$. ■

The analysis above suggests that a ban on bundling may improve social welfare, but such a ban is effective only if the system maker starts to sell applications that work with the old system. Otherwise, a virtual tie remains in spite of the absence of physical bundling, since consumers still have to upgrade in order to use new applications.

IV. Extensions

A. Uncertainty In Consumer Valuation

In the monopoly case of the basic model, consumers' valuations of B are distributed on the support of $[a, b]$ and each consumer is assumed to know her valuation when making the initial purchase of the system. This is somewhat unrealistic. In this extension, I assume that consumers' valuations still have the same distribution, but a consumer learns her valuation of B only after its introduction by the monopolist in the second period.

Clearly, this does not change the monopolist's second period problem. Now I verify that the solution to the monopolist's commitment problem does not change under the new specification in timing.

In the second period, each consumer in $[a, u^*]$ gets a utility of $N\{F(u^*) + a_{12}[1 - F(u^*)]\}$ and each consumer in $[u^*, b]$ gets $u - p + N\{F(u^*) + a_{12}[1 - F(u^*)]\}$. Uncertainty in valuation means that consumers are identical ex ante, hence they have the same willingness to pay for the system. This determines the original system price, which will be $N\{F(u^*) + a_{12}[1 -$

$F(u^*)]\} + \int_{u^*}^{b} uf(u)du - u^*[(1 - F(u^*)]$. It is also easy to find the price of the upgrade $p = u^* + N\{a_{21}F(u^*) + [1 - F(u^*)]\} - N\{F(u^*) + a_{12}[1 - F(u^*)]\}$.

Therefore, the monopolist's total profits are $\max_{u^*} N\{F(u^*)+a_{12}[1-F(u^*)]\}+\int_{u^*}^{b} uf(u)du - u^*[(1 - F(u^*)] + [1 - F(u^*)](u^* + N\{a_{21}F(u^*) + [1 - F(u^*)]\} - N\{F(u^*) + a_{12}[1 - F(u^*)]\})$. By the envelope theorem, $\frac{\partial\pi}{\partial a_{12}} = \frac{\partial\pi}{\partial a_{21}} = [1 - F(u^*)]F(u^*)N' > 0$. Hence $a_{12} = a_{21} = 1$ (full compatibility) maximizes monopoly profits. Introducing uncertainty does not affect the result.

B. Uncertainty in entry cost

In the competitive case of the basic model, I assume that the system maker knows the entry cost of the independent supplier and thus can fine-tune its entry accommodation strategy. Now I consider the case in which the independent supplier's entry cost is private information.

Suppose that entry costs, F, are represented by a cumulative distribution function $G(F)$. The independent supplier enters if and only if $F \leq \pi_e = \frac{1}{9}\frac{(3t-n(3-2a_{21}-a_{12}))^2}{2t-n(2-a_{21}-a_{12})}$. So the system maker's expected total profits are $E(\pi_m) = \pi_m(\text{no entry}) + [\pi_m(\text{entry}) - \pi_m(\text{no entry})]G(\pi_e)$, where $\pi_m(\text{no entry}) = u + n - t$. Let $\Delta\pi = \pi_m(\text{entry}) - \pi_m(\text{no entry})$. Both $\Delta\pi$ and π_e increase with a_{12} so we must have $a_{12}^* = 1$. From the proof of 4, we know that $\Delta\pi$ decreases with a_{21} but π_e increases with a_{21}, hence $E(\pi_m)$ is maximized at $a_{21}^* \in (0, 1)$. Therefore, backward compatibility is still optimal.

Example 2 *Suppose that entry costs are uniformly distributed on* $[0, t/2]$. *In this case,* $E(\pi) \propto \Delta\pi \cdot \pi_e = n(a_{12} - a_{21})\frac{[3t-n(3-2a_{12}-a_{21})]^3}{[2t-n(2-a_{12}-a_{21})]^2}$. *Since* $\frac{\partial}{\partial a_{12}}(\Delta\pi \cdot \pi_e) = \frac{n(3t-3n+na_{12}+2na_{21})^2}{(2t-2n+na_{12}+na_{21})^3} * (5nta_{12} - 12nt + 7nta_{21} + 6n^2 + 6t^2 - 5n^2a_{12} - 7n^2a_{21} + n^2a_{12}a_{21} + 2n^2a_{12}^2 + 3n^2a_{21}^2) > 0$, *we have* $a_{12}^* = 1$. *The first-order condition with respect to* a_{21} *is* $\frac{\partial}{\partial a_{21}}(\Delta\pi \cdot \pi_e) = \frac{n(3t-3n+na_{12}+2na_{21})^2}{(2t-2n+na_{12}+na_{21})^3} * (13nta_{21} - nta_{12} - 12nt + 6n^2 + 6t^2 + n^2a_{12} - 13n^2a_{21} + 5n^2a_{12}a_{21} - 3n^2a_{12}^2 + 4n^2a_{21}^2) = 0$. *Substituting* $a_{12}^* = 1$ *into the FOC, we get* $a_{21}^* = 0.443t/n$.

Note that if the entry cost is publicly known and equals the expected value in the private information case, i.e., $F = t/4$, then $a^*_{21} = 0.382t/n$, quite close to the solution in the private information case.

C. New Customers

In the basic model, the system maker's choice of tying is driven by its desire to increase the price of the original system. One may wonder whether its incentive to tie the application changes if some customers do not make system purchases until the second period. To answer this question, I extend the basic model by assuming that some customers (in the size of s) enter the market in the second period and that they are otherwise identical to customers that enter in the first period.[22]

In the monopoly case, it is clear that the system maker's ex post incentive to introduce backward compatible upgrade is strengthened because new customers' purchases of the upgrade increases its pull to old customers. At the same time, the system maker's ex ante incentive to make a commitment to full compatibility remains the same. It is not difficult to see why: the system maker's total profits will have an additional term related to the network benefits of new customers, $sN[1 - F(u) + s + a_{12}F(u)]$, but it is increasing in a_{12} and independent of a_{21}.

In the competitive case, the existence of new customers gives the system maker an incentive to unbundle its application, but unbundling is advantageous only if the number of new customers is sufficiently large. To see this, we first observe the following: when the system maker sells an upgrade tied with a new application, both the system maker and the independent supplier have an incentive to price discriminate: the system maker has an incentive to set a discounted upgrade price for owners of the original system in order to prevent them from delaying their first-period purchases; conversely, the independent supplier has an incentive to give a discount to owners of the upgrade, since the upgrade already integrates

[22] I do not specify an exogenous attrition process because attrition is endogenous in my model: first-period consumers who choose not to upgrade leave the market in the second period.

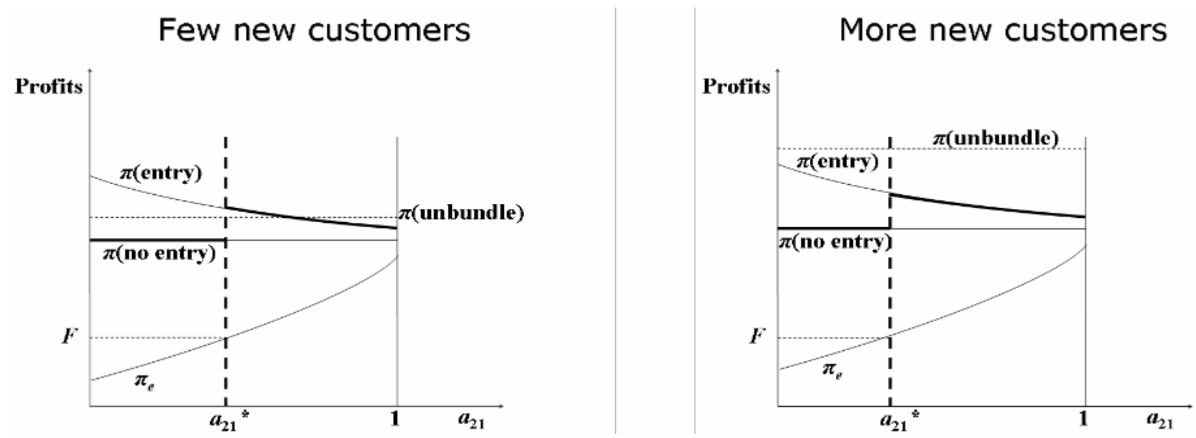

Figure 4: The system maker always benefits from entry of an independent supplier. It earns a higher profit from unbundling than from bundling with full compatibility. It may or may not choose to bundle (with backward compatibility), depending on the relative size of new customers.

the system maker's new application. As is standard in third-degree price discrimination, a firm's pricing strategy can thus be determined separately in each segment.[23] Therefore, the earlier analysis on firms' pricing strategies involving old customers continues to apply.

Now consider the new customer segment. It is rather straightforward to show that the system maker's total profits from new customers are higher with the existence of an independent supplier of applications and is independent of its choice of compatibility. At the same time, the equivalence between unbundling and full compatibility breaks down. Recall that the equivalence holds in the basic model because old customers buy an upgrade after their system purchases and the system maker cannot precommit to an upgrade price in the first period. New customers, however, buy the system and the application simultaneously, therefore a commitment to a low price in the application is easily available. Since the system is essential for the use of the application, according to Whinston (1990, Proposition 3), it is more profitable not to tie.

Taking into account the above two effects (see Figure 4) and weighing them against the benefits of tying in the segment of old customers, we can conclude that the system maker

[23]It is easy to verify that the resulting prices do not create arbitrage opportunities.

continues to tie when it expects relatively few new customers and will choose not to tie if it expects a large number of new customers.

D. Myopic Consumers

Although my analysis is based on the assumption of forward-looking consumers, it is not difficult to find the system maker's optimizing strategy when there are myopic consumers. A commitment in the first period will not increase a myopic consumer's willingness to pay, so the system maker will also act myopically and reverse its strategy completely: in the monopoly case, it will choose to integrate the application into an upgrade that is backward compatible; but in the competitive case, it will sell its application as a separate product or sell an upgrade that is fully compatible with the old system. In both cases, the system maker can introduce two systems to separate myopic consumers from forward-looking consumers, with the latter group paying a premium for a system that offers a higher second-period utility.

V. Discussions

Computer operating systems (OS) are characterized by network externalities. The dominant player in the OS market, Microsoft, has been constantly adding new features into its Windows OS in the form of system upgrades. Its bundling practice has been the subject of several highly controversial antitrust lawsuits. My model provides a framework to study Microsoft's bundling strategy and related antitrust cases.

A. European Commission v. Microsoft

In March 2004, The European Commission concluded that Microsoft Corporation broke European Union (EU) competition law by leveraging its near monopoly in the market for PC operating systems onto the markets for media players. The Commission cites Microsoft's

Release Date	Media player	System Requirement
1995	WMP 5.1	Windows 95
Late 1997	RealPlayer 5	Windows 3.1
June 1998	WMP 6	Windows 95
July 1998	RealPlayer 6	Windows 95
Nov. 1999	RealPlayer 7	Windows 95
June 2000	RealPlayer 8	Windows 95
July 2000	WMP 7	Windows 98
Dec. 2001	RealOne (v9)	Windows NT
Jan. 2003	WMP 9	Windows 98
April 2004	RealPlayer 10	Windows NT
Oct. 2004	WMP 10	Windows XP

Windows Version	Obsolescence Date in WMP	Obsolescence Date in RealPlayer
3.1	1995	July 1998
95	July 2000	Dec. 2001
NT 4.0[a]	July 2000	current
98	October 2004	current
ME	October 2006	current
2000[b]	October 2004	current
XP	Current	current

[a,b]Windows NT and 2000 are server products.

Table 1: Release dates and system requirements of major releases of WMP and its main competitor, RealPlayer, in the last decade. The "obsolescence date" of a Windows OS is defined as the release date of a media player that discontinues its support of the OS.

bundling of Windows Media Player (WMP) into Windows as "an example of a more general business model which deters innovation and reduces consumer choice in any technologies which Microsoft could conceivably take interest in and tie with Windows in the future." Microsoft was ordered to offer a version of its Windows OS without Windows Media Player. In addition, Microsoft was fined a record $600 million for abusing its market power in the EU.

The left column in Table 1 lists the dates and system requirements of major releases of WMP and its main competitor, RealPlayer, in the last decade.[24] The right column is derived from 1a and lists the "obsolescence dates" of Windows operating systems, defined as the release date of a media player that discontinues its support of the OS.

An interesting pattern emerges: RealPlayer consistently supports more versions of the Windows OS than Microsoft's own WMP, although Microsoft often rationalizes its bundling strategy by claiming that its own applications can best utilize the operating system. In July 2000, Microsoft released WMP 7, which was bundled into Windows 98 but could not be installed on Windows 95. Almost concurrently, RealPlayer 8 was released and supported

[24]The information presented in this section has been obtained from news wires and articles on Lexis-Nexis. Authors and titles of the news articles are listed in the Appendix.

both Windows 95 and Windows 98. The introduction of WMP 10 and RealPlayer 10 in 2004, by Microsoft and RealNetworks respectively, follows a similar pattern. At the same time, casual observations suggest that Microsoft tends to provide backward compatibility in its system upgrades. Taken together, these observations are consistent with my model's prediction that a monopoly system maker uses a combination of bundling and backward compatibility in its upgrades to better extract monopoly rents.

Although it is arguable whether antitrust policy should be aimed at protecting a particular market player, my model does provide qualified support to the EU commission's central contention that Microsoft's bundling strategy is detrimental to its competitors as well as society. At the same time, contrary to the commission's claim that Microsoft uses bundling to destroy its rivals, my model finds that Microsoft may have an incentive to preserve competition in the application markets. This finding appears consistent with the robust competition that we observe in today's media player market.[25]

B. United States v. Microsoft

In 1998, the United States Department of Justice (DOJ) and twenty U.S. states filed a lawsuit against Microsoft, accusing it of illegally bundling Internet Explorer (IE) into Windows 98. Table 2 lists the dates and system requirements of major releases of IE and its main competitors, first Netscape then Mozilla Firefox, in the last decade.

The pattern emerging in Table 2 is similar to what we observe in the media player market. Both Internet Explorer 6 and 7 are unavailable for users of old versions of Windows, whereas Microsoft's competitors provide continued support to those users. However, contrary to my model prediction, Microsoft did not tie the use of IE to Windows 98; the IE version bundled with Windows 98 was also available to users of earlier versions of Windows.

[25] It should be noted that the media player market is also an example of two-sided markets, in which content providers and final consumers constitute the two sides that trade with each other. Two-sided markets are characterized by indirect network effects, a feature not accounted for in my model. Choi (2006) provides a careful analysis of tying that takes into account the peculiarities of two-sided markets.

Release Date	Browser	System Requirement
Aug. 1996	Netscape 3	Windows 3.1
Aug. 1996	IE 3	Windows 3.1
June 1997	Netscape 4	Windows 3.1
June 1997	IE 4	Windows 3.1
March 1999	IE 5[a]	Windows 3.1
April 2000	Netscape 6[b]	Windows 95
Aug. 2001	IE 6	Windows NT
Aug. 2002	Netscape 7	Windows 95
Nov. 2004	Firefox 1	Windows 95[c]
Oct. 2006	IE 7	Windows XP
Oct. 2006	Firefox 2	Windows NT

Windows Version	Obsolescence Date in IE	Obsolescence Date in Netscape/Firefox
3.1	June 2000	April 2000
95	August 2001	Oct. 2006
NT 4.0[d]	October 2006	current
98	October 2006	current
ME	October 2006	current
2000[e]	October 2006	current
XP	Current	current

[a]IE 5.5, released in June 2000, cannot run on Windows 3.1.

[b]Netscape 5 was canceled and never released.

[c]The installation of Firefox 1.x on Windows 95 requires a system file (OLEAUT32.DLL) update (http://community.wvu.edu/ ast002/mozilla/qa.html#win95).

[d,e]Windows NT and 2000 are server products.

Table 2: Release dates and system requirements of major releases of IE and its main competitor, first Netscape then Firefox, in the last decade. The "obsolescence date" of a Windows OS is defined as the release date of a web browser that discontinues its support of the OS.

Clearly, the web browser market has two distinctive features that are not captured by my model. First, Microsoft maintains that IE is an integrated part of its operating system and unbundling is technically infeasible; second, instead of pure complements, a web browser can be a potential substitute for the Windows operating system. Therefore, other possible motivations for Microsoft's bundling of IE are worth exploration (Carlton and Waldman, 2002).

C. When is Bundling Harmful?

Microsoft makes a point by arguing that, "most products result from combining a variety of individual components. Indeed, product innovation results in no small measure from such integration." A question naturally arises: when is it harmful for a dominant firm to incorporate new components or features that demonstrably improve its finished product?

In my analysis, the system maker's profits and social welfare are not affected by its choice of tying and compatibility if consumers' valuations of the upgrade are sufficiently homogeneous, because there will be no loss of network benefits when everyone makes the same upgrade decision. Therefore, in my model tying is harmful only if there is a substantial degree of variation in consumer preferences, relative to the network effects, over the tied components. This criteria is considerably more stringent than the legal test proposed by the EU commission that bundling is unlawful unless the dominant firm can prove that the integration is "indispensable" to achieving pro-competitive benefits.

D. What is the Appropriate Remedy?

Microsoft started offering Windows XP N, a version of Windows without a bundled media player in European markets to comply with the EU ruling. However, there is virtually no demand for the stripped-down version. This raises questions about the effectiveness of the EU's antitrust ruling, particularly as Microsoft has been allowed to offer Windows XP N for the same price as the standard version of Windows XP.

My model shows that the physical tie between the application and the upgrade is not so important as the incompatibility between the application and the original system. Inefficient upgrades occur because consumers who want new applications are forced to abandon the original system. In other words, the real underlying problem is tying but not bundling. A mere restriction on bundling fails to address the fundamental tying problem.

VI. Conclusions

This paper explores a system maker's incentives to provide upgraded versions of its system and its choice of compatibility. I show that tying new applications into an upgrade that is backward compatible generates strictly higher profits when network externalities are present. As a result, the system maker may introduce more upgrades than optimal. A commitment not to upgrade or a commitment to full compatibility may increase the system maker's total profits. However, if the system maker faces competition from an independent supplier of applications, then it may again introduce the upgrade, even though a commitment of not doing so is available and socially optimal.

The market conduct of a monopoly system maker such as Microsoft has been under constant scrutiny by regulators. A major concern of the regulators is its use of tying as an exclusionary device. My paper, however, suggests that their concern may have been misplaced. Ironically, tying is profitable in my model precisely because it commits the system maker to a vigorous competition in the application market. In this sense, my model vindicates the view, expounded by Chicago School scholars, that a monopolist of one product never finds it worthwhile to reduce the level of competition in the market of a complementary product. At the same time, my model shows that tying can be harmful even when its use by a monopolist does not lead to exclusion of rivals.

Although my analysis provides arguments in favor of the hypothesis of planned obsolescence, its welfare implications are less clear. Even in the simple models considered here, which ignores a number of other possible motivations for the practice, the impact of tying on welfare depends on the market structure and model parameters. Moreover, my results are obtained under an assumption of weak network externalities. This means that welfare loss, if any, may not be significant enough to warrant heavy-handed government interventions.

While the models presented in this paper are sufficiently general, there are some strong assumptions that can potentially be relaxed. First, the models ignore entry into the system market; second, the system maker's incentive to engage in R&D is assumed to be exogenous. Future studies that incorporate more realistic elements can help us better understand the issues discussed in this paper.

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