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PREEMPTIVE R&D, RENT DISSIPATION AND THE "LEVERAGE THEORY"

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Abstract

This paper provides a new perspective on the validity of the so-called "leverage theory". In a model of preemptive innovation in "systems" markets, I examine the effect of bundling on R&D incentives. I find that bundling provides a channel through which monopoly "slack" in one component market can be shifted to another, with the effect of mitigating rent dissipation in the systems market. Bundling can be profitable if this beneficial effect of reduced rent dissipation outweighs the negative effect of intensified price competition. After demonstrating the private optimality of bundling, its welfare implications are considered. There is a discrepancy between the market outcome and the socially optimal outcome which can be explained in terms of externalities conferred on consumers' surplus and the rival firm's profits due to bundling. Finally, the results can be reinterpreted to analyze the relationship between compatibility decisions and R&D incentives in mix-and-match models.

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I. Introduction

According to the "leverage theory", a multi-product firm with monopoly power in one market can monopolize a second market using the leverage provided by its monopoly power in the first market. Tie-in sales, also known as bundling arrangements, have been favorite examples to illustrate this point. A tie-in sale is a practice in which a seller of the "tying" good makes the sale of its monopolized product conditional upon the purchaser also buying some other product (tied good) that may be competitively supplied. By foreclosing sales in the tied good market, tying allegedly provides one mechanism to extend monopoly power from one market to another. However, the logic of the theory has been criticized and subsequently dismissed by a number of economists and legal commentators who argue that the use of leverage to affect the market structure of the tied good (second) market is impossible [see Bowman (1957), Posner (1976), and Bork (1978)].[1]

I refute these criticisms by considering a situation in which (non-price) competition for the monopoly position entails wasteful dissipation of industry rents. More specifically, I study the possibility of leverage, i.e. extending monopoly power in one market to another, in a model of preemptive innovation first introduced by Gilbert and Newbery (1982).

To highlight the importance of introducing other forms of nonprice competition for the leverage theory, I first consider the case of a simple pricing game preceded by a tying decision. The approach is based on a new development in the theory of bundling or tying which emphasizes strategic aspects of bundling decisions and their consequences for the ensuing price game [Whinston (1990)]. I illustrate that tying arrangements intensify price competition and can only reduce the profit of the tying firm, thereby confirming the impossibility result of leverage by legal commentators originating in the Chicago school.

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[1] Bowman, for instance, claims that "leveraging, in a word, is no more plausible than lifting oneself by ones bootstraps." These arguments, often associated with the University of Chicago oral tradition, are traceable to Aaron Director.

However, it will be demonstrated that we can have a situation in which tying is a profitable strategy once the model is extended to allow for competition in R&D. I examine the effect of tying on the incentive for R&D. I find that tying provides a channel through which monopoly "slack" in one market can be shifted to another, with the effect of mitigating rent dissipation in the overall markets. I point out that tying can be profitable if this beneficial effect of reduced rent dissipation outweighs the negative effect of intensified price competition.

The intuition for the effect on rent dissipation is as follows. In a model of preemptive innovation, the extent to which rent is dissipated typically depends on the degree of initial asymmetry between competitors; the more disparate their initial strategic positions the less rent is dissipated. For instance, in Fudenberg and Tirole's (1985) technology adoption model with symmetric firms, monopoly rent is completely dissipated[2] whereas no rent is dissipated if the initial asymmetry is so large that a weaker firm poses no threat to a stronger firm (Katz and Shapiro, 1987). Consequently, if a firm initially possesses a significant advantage in one market, it can engage in R&D as if there were no rival in that market. In this case, it may be advantageous for the firm to engineer a tying arrangement in order to utilize the unused monopoly slack in this market to bolster the strategic position in the other market. This pooling of strategic strengths in two markets can lead to the leverage of monopoly power from one market to another and can be successfully used to exclude rival firms from markets, which otherwise would have been profitable.

After demonstrating the private optimality of tying, its impact on social welfare is analyzed. I consider two cases according to the initial positions of two firms producing complementary products. In the case where one firm has advantages in both markets, it is shown that the market outcome and the socially optimal outcome coincide. As a result, privately optimal tying arrangements are also welfare-enhancing. In the other case where

[2]The hypothesis of monopoly rent dissipation was first proposed by Posner (1975).

each firm has initial advantages in separate markets, it is shown that there is an excessive incentive for tying arrangements. The result can be explained in terms of externalities conferred on consumers' surplus and the rival firm's profits due to tying arrangements: consumers benefit due to intensified price competition whereas the rival firm loses because its business is stolen. It turns out that the negative effect of business stealing dominates the beneficial effect of consumer surplus increase.

In a recent paper, Whinston (1990) also re-examines leverage theory and shows that tying can indeed be an effective, and profitable, strategy in altering the market structure for the tied good. He demonstrates that the criticisms of the Chicago school are valid only when the market of the tied good is competitive and has a constant returns to scale technology. If scale economies in the production technology are allowed, the leverage theory may be vindicated. By assuming an oligopolistic market structure in the (potentially) tied good market, Whinston was able to generate a strategic incentive to bundle that was nonexistent in the purely monopolistic or perfectly competitive markets, which were the presumed market structures in the conventional discussions of price-discrimination or leverage theories of bundling.[3] However, there are major differences between my paper and Whinston's. First, the mechanism by which leverage occurs is completely different. The result in his model hinges crucially on the possibility of inducing exit of the rival firm. In contrast, in my model the price effect of tying arrangements is

[3]Numerous theories have been proposed to explain the motives for the practice of bundling and to find the ensuing anti-trust and welfare implications. The most prominent view is that commodity bundling serves as a vehicle for price discrimination. Papers in this tradition start with Stigler (1963) and include Adams and Yellen (1976), and Schmalensee (1984) among others. They demonstrate that bundling can increase profit even in the absence of any cost advantage to providing goods in combination or interdependency in demand for component products. More general conditions for the optimality of bundling are provided in McAfee, McMillan and Whinston (1989) who show that bundling is always optimal when reservation values are independently distributed in the population of consumers. A variation on this theme is the metering argument in which the purchase of an indivisible machine is accompanied by the requirement that all complementary variable inputs be purchased from the same company. Other explanations given in this literature include monitoring the cheating on a cartel price, evasion of price controls, protection of goodwill reputation, economies of joint sales, etc.

always negative since entry and exit is not an issue. Rather, the benefit of tying arises from its role in reducing rent-dissipation in R&D competition. Secondly, in his welfare analysis, the socially beneficial effect of bundling stems from its price-discriminatory role whereas in my paper the effect is due to a reduction in socially wasteful rent dissipation.[4]

In a related paper, DeGraba (1994) considers a seller with power in a differentiated good market also sells a homogeneous good that is sold in a *free entry* market with fixed cost. In his model, as with my results, tying lowers the effective price of the two goods and creates increased profit for the seller. He shows that tying provides a mechanism to divert sales from competitors. These additional sales are profitable at the margin even in free entry (zero profit) equilibrium. The reason is that the price in free entry market is higher than the marginal cost in the presence of fixed cost. A tying firm also forecloses its competitors. In contrast to my paper, the effect of foreclosure, however, is always beneficial for the society because there was excessive entry to begin with [see Mankiw and Whinston (1986)]. Even though there is exit by competing firms, there is no offsetting effect of lost profits for the rivals (business stealing effect) because they were earning zero profit anyway due to free entry assumption. Therefore, the possibility of welfare-reducing leverage does not arise in his model.

To model R&D competition, I build on the work of Gilbert and Newbery (1982), Fudenberg and Tirole (1985), and Katz and Shapiro (1987). Their papers, however, focus on various aspects of R&D competition in a single market and do not consider the possibility of consolidating the R&D incentives in different markets through tying

[4]Carbajo, De Meza and Seidmann (1990) also provide a strategic incentive for bundling. As in this paper, they are not concerned with the rival's entry or exit decisions. Instead, they show that bundling may be profitable because it induces one's rival to price less aggressively. This is due to their assumption that consumers are heterogeneous and can have different reservation values. However, for a given individual the reservation prices for the two goods are identical. In their model, tie-in provides a partitioning mechanism to sort consumers into groups with different reservation price characteristics; the firm with bundled products sells to high reservation consumers while the competitor sells to low reservation consumers. As a result, the rival firm can raise its price in equilibrium. The overall effect on the market is reduced competition.

arrangements. Therefore, the issue of leverage does not arise.

Finally, the mechanism by which slack in one market is used to improve market position in another market is reminiscent of the mechanism in Bernheim and Whinston (1990). Incentive constraints are pooled across markets to improve collusiveness.

The remainder of the paper is organized in the following way. In section II, I start with a simple two stage model in which price competition is preceded by an irreversible bundling decision. I reconfirm the critics view that leverage theory is implausible. Section III, the core of the paper, extends the model by allowing for competition in R&D. I demonstrate formally how monopoly power in one market can be extended to another market through using "monopoly slack" in R&D competition. Market outcomes are compared with the social optimum and possible sources of inefficiency are identified. Concluding remarks follow.

II. Incentives for Tying in the Absence of R&D

I consider a system market comprised of two complementary products A and B to be used on a 1-to-1 basis. Consumers, whose total measure is normalized to 1, are assumed to be identical and have at most one unit of demand for the system valued at V. Since the two products are to be purchased together, only the sum of the two component prices will matter for the consumer's purchase decision. There are two firms (indexed by i) in the market, whose unit production costs for components A and B are denoted by a_i and b_i, respectively, where i=1, 2. To focus on the strategic motive for bundling, we also assume that there is no cost advantage or disadvantage associated with bundling. Let $c_i = a_i + b_i$ denote firm i's system cost (total unit cost for the system).

First, I establish the fact that unbundling always (weakly) dominates a bundling strategy if the market structure is oligopolistic and the production cost of each firm is given and cannot be altered. To see this, I consider a two-stage game.

In the first stage, each firm decides whether or not to bundle the two products. As in Whinston(1990) and Carbajo *et al.* (1990), I assume that this precommitment is made possible through costly investments in product design and the production process. A price game ensues in the second stage with the bundling decision in the previous stage as given. The timing assumption reflects the fact that bundling decision through product design is a longer term decision that cannot be modified easily compared to the pricing decision. I assume homogeneous products and Bertrand competition. The outcomes are described below and depend on each firm's bundling decision in the first stage.

(i)No Bundling

If the two products are not bundled, the consumers will buy each component from the vendor who charges the lowest price as long as the sum of the two prices does not exceed the reservation value V. Let us assume that V is sufficiently large compared to the production costs so that this constraint does not bind. With consumers' ability to mix and match components from different vendors, competition will be at the component level. Bertrand competition ensures that in each component market the firm with the lower production cost will win the whole market by selling at the production cost of the rival firm (minus ε); the prices in component markets A and B will be realized at $\max(a_1, a_2)$ and $\max(b_1, b_2)$, respectively. The total price consumers pay for the system is $\max[a_1, a_2] + \max[b_1, b_2]$.

(ii)Bundling

If two products are bundled, the two products must be purchased from the same vendor. Consequently, only the sum of the two component prices (system price) will matter for the consumer's purchase decision. The firm with the overall advantage in production costs will make all sales at the system cost of the rival firm. The total price consumers pay for the bundled system is $\max[a_1+b_1, a_2+b_2]$, which is strictly less than $\max(a_1, a_2) + \max(b_1, b_2)$ unless one firm has cost advantages in both products, in which case it can be verified that bundling has no effect. Therefore, if the bundling decision is

irreversible and made before price competition, unbundling will be a (weakly) dominant strategy for both firms (if one firm has cost advantages in both products, then the compatibility configuration has no effect).[5] Unbundling softens price competition by localizing it to two markets and serves the role of puppy-dog ploy when each firm has an advantage in separate markets and entry and exit is not a concern.[6]

Note that given cost levels for each firm, unbundling promotes *static* efficiency since it leads to production of each component by the most efficient supplier. With bundling, however, production will come from the producer who has the lowest overall production costs. Therefore, it is possible that the actual producer can have a higher production cost in one of two components. In this model, the social and private incentives for (un)bundling coincide.

III. The Leverage Theory of Tying in the Presence of R&D

In this section, I amend the basic model of Section II by introducing the possibility of R&D, thereby endogenizing the final production cost of each firm. More specifically, I analyze a three stage game in which the two stages of the previous game (bundling decision and price competition) are interceded by R&D competition. In other words, in the first stage, the two firms decide whether or not to make their components compatible with their rival's, given their *pre* R&D cost levels for each product. In the next stage, the two firms engage in cost reducing R&D activities. A price game ensues in the final stage with the cost structure inherited from the realizations of R&D. As usual, I analyze the overall game

[5]Matutes and Regibeau (1988) derives a similar result in a two dimensional product differentiation model. The compatibility choice in their model also has the effect of raising demand due to increased variety *in addition to* the price softening effect. Contrast this result with that of Economides (1991) who derives that the game of bundling exhibits a Prisoner's Dilemma payoff structure in which (mixed) bundling is a dominant strategy.

[6]However, bundling, which is a commitment to aggressive pricing in the face of competition, can be a profitable strategy if the firm engineering it succeeds in the deterrence of entry or inducement of exit by the rival firm (In the terminology of Fudenberg and Tirole (1984), bundling is a top dog strategy). See Whinston (1990) for details.

by proceeding with backward induction.

There are many different ways to model R&D competition [see Reinganum (1989) for a survey]. In this paper, I adopt the simplest one by assuming that R&D competition takes place in the form of a simple deterministic bidding game [Gilbert and Newbery (1982), Riordan (1992), and Vickers (1986)]. Consider a simple auction in which bidding occurs in terms of the desired level of unit cost reduction. The winner of the patent race is the one who bids the highest level of cost-reduction. The winning bidder is then assumed to pay an amount which depends on the actual winning bid, i.e., the differential between his *post* R&D and *pre* R&D unit cost level. More specifically, if a firm with an initial cost level of c wins the auction by bidding Δ, the firm pays R&D expenditures of $\Phi(\Delta)$ and its post R&D cost becomes $c-\Delta$. I assume that $\Phi'>0$, $\Phi''>0$, and $\Phi(0) = 0$ which captures the idea that the cost of R&D is increasing at an increasing rate as the size of innovation increases. Finally, the loser of the auction does not forego his bid.

Admittedly, this specification of R&D competition is special in many respects. However, it should be pointed out that the main results in the paper are not dependent on the specifics of the bidding game. For instance, I could have assumed that the bidding is done in terms of the desired cost level after R&D without affecting the main results of the paper. Perhaps the most controversial is the assumption that the loser does not lose his bid since a forfeited bid can be interpreted as a sunk cost in R&D. In section IV, however, I model R&D competition as a simple stopping game of technology adoption in the manner of Gilbert and Newbery (1982). Since the cost is incurred only when the adoption of a new technology occurs, the assumption that the loser (the one who is preempted) does not forfeit his bid is more natural in this dynamic setting. Therefore, the simple bidding model of R&D specified above can be interpreted as an idealization of the situation where bidding occurs in terms of the adoption timing of a new technology.

To understand R&D bidding in the complementary goods markets, it is useful to begin by analyzing a stand-alone market. Suppose that there are two firms 1 and 2 who

have initial unit production costs of z_1 and z_2, respectively. Without loss of generality, assume $z_2 \geq z_1$. Let $\delta = z_2 - z_1$ represent the cost advantage held by firm 1. Then, firm 2 which initially has a relative cost disadvantage of δ, gets a net profit of $\pi(\Delta, \delta)$ if it wins the auction by bidding Δ, where

$$\pi(\Delta, \delta) = \max[\Delta-\delta, 0] - \Phi(\Delta) \qquad (1)$$

For each value of δ let $\Delta(\delta)$ be the highest Δ such that $[\Delta - \delta] - \Phi(\Delta)= 0$, if such a Δ exists, i.e.;

$$[\Delta(\delta) - \delta] - \Phi(\Delta(\delta))= 0 \qquad (2)$$

Then, the maximum bid firm 2 (the higher cost firm) is willing to make, $\overline{\Delta}_2$, which depends on the size of its initial relative disadvantage (δ), is given by $\Delta(\delta)$. Note that $\Delta(\delta)$is a decreasing function of δ [see Figure 1].

If there is no positive value of $\Delta(\delta)$ that satisfies Eq. (2), we define $\overline{\Delta}_2$ to be zero because, in this case, participation in the auction is not worthwhile for firm 2. This case arises when the initial disadvantage (δ) facing firm 2 is sufficiently large. More precisely, let us define

$$\overset{o}{\Delta} = \underset{\Delta}{\operatorname{argmax}}\, [\Delta - \Phi(\Delta)] \qquad (3)$$

$$\overset{o}{\pi} = \max\, [\Delta - \Phi(\Delta)] = \overset{o}{\Delta} - \Phi(\overset{o}{\Delta}) \qquad (4)$$

In other words, $\overset{o}{\pi}$ is the upper bound for the net benefit of engaging in cost-reducing R&D. Then, bidding is not worthwhile for the higher cost firm when the maximum benefit from innovation is not large enough to overcome the initial cost disadvantage, i.e.,

$$\max\, [\Delta - \Phi(\Delta)] - \delta = \overset{o}{\pi} - \delta \leq 0$$

Therefore, the higher cost firm's maximum willingness to bid can be written as

$$\overline{\Delta}_2 = \begin{cases} \Delta(\delta), & \text{if } \delta < \overset{o}{\delta}\ (=\overset{o}{\pi}) \\ 0, & \text{if } \delta \geq \overset{o}{\delta}\ (=\overset{o}{\pi}) \end{cases}$$

In contrast, firm 1 (the lower cost firm) with initial advantage of δ is willing to bid up to $\overline{\Delta}_1$ which is given by:

$$[\overline{\Delta}_1 + \delta] - \Phi(\overline{\Delta}_1)= 0 \qquad (5)$$

It can be easily verified that $\bar{\Delta}_1$ is always larger than $\bar{\Delta}_2$, meaning that firm 1 will always outbid firm 2 in the auction. In accordance with Katz and Shapiro (1987), I may call $\overset{o}{\Delta}$ the stand-alone incentives of R&D and $\bar{\Delta}_i$, firm i's preemptive incentives, respectively. Then, the equilibrium winning bid by firm 1, Δ^*, depends on the relative magnitudes of the stand-alone and preemptive incentives, and is given by $\max[\overset{o}{\Delta}, \bar{\Delta}_2]$.[7] Note that $\Delta(\delta) \geq \overset{o}{\Delta}$ for the parameter space where $\Delta(\delta)$ is well defined (i.e., $\delta \leq \overset{o}{\delta}$). If $\delta > \overset{o}{\delta}$, the initial cost asymmetry is sufficiently large to secure the lower cost firm a virtual monopoly position in R&D competition. In this case, the lower cost firm will maximize its net profit from R&D by bidding $\overset{o}{\Delta}$. We conclude that the winning bid in equilibrium is given by:

$$\Delta^* = \begin{cases} \Delta(\delta), & \text{if } \delta < \overset{o}{\delta} \ (= \overset{o}{\pi}) \\ \overset{o}{\Delta}, & \text{if } \delta \geq \overset{o}{\delta} \ (= \overset{o}{\pi}) \end{cases} \tag{6}$$

The net equilibrium profit from winning the auction depends on the initial cost differential, which can be written as:

$$\pi^*(\delta) = \begin{cases} \Delta(\delta) - \Phi[\Delta(\delta)] = \delta \text{ (by Eq. (2))}, & \text{if } \delta < \overset{o}{\delta} \ (= \overset{o}{\pi}) \\ \overset{o}{\pi} \ (= \overset{o}{\delta}), & \text{if } \delta \geq \overset{o}{\delta} \ (= \overset{o}{\pi}) \end{cases} \tag{7}$$

As in the rent dissipation literature, we draw the conclusion that wasteful competition dissipates industry profits unless the initial asymmetry between two firms is large enough to render a competitive threat by a weaker firm meaningless [see Fudenberg and Tirole (1987) and Katz and Shapiro (1987)]. I summarize the R&D bidding game in a single market in the following lemma.

Lemma 1. Firm 1 outbids firm 2 in the R&D game and its bid will be at $\max[\overset{o}{\Delta}, \bar{\Delta}_2]$. We have $\bar{\Delta}_2 > \overset{o}{\Delta}$ when $\delta < \overset{o}{\delta}$. As a result, we have efficiency in R&D if and only if $\delta \geq \overset{o}{\delta}$, where $\overset{o}{\delta} = \overset{o}{\pi}$ (= max [$\Delta - \Phi(\Delta)$]). Otherwise, there will be excessive R&D due to competition.

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[7]As in Whinston (1990), I ignore equilibria in which firm 2 bids above $\bar{\Delta}_2$ and loses in the auction. These equilibria involve weakly dominated strategies and can be eliminated by using the notion of trembling-hand perfect equilibria (Selten [1975]).

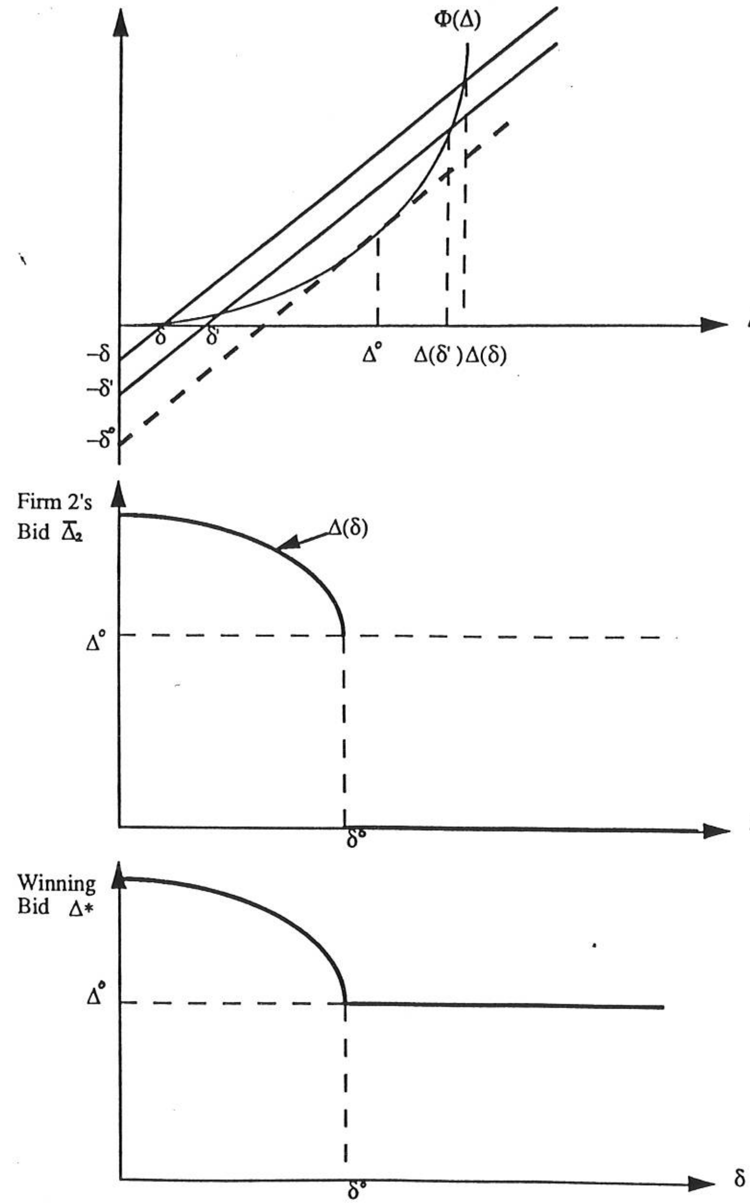

Figure 1: Bidding Equilibrium

Now I analyze the R&D bidding in complementary markets A and B. The focus of the analysis will be on how R&D bidding incentives are affected by the firm's prior bundling decisions.

(i)No Bundling

Without bundling, consumers retain the ability to mix and match components from different vendors. As a result, they purchase each component from whoever sells at the lowest price, which implies that each market can be analyzed separately, since the benefit of R&D in one market is independent of the outcome in the other.[8]

Suppose that the *pre* R&D cost of each firm in each market is given by a_i and b_i, respectively, where i=1, 2. Let $\delta_A=a_2-a_1$ and $\delta_B=b_2-b_1$ represent firm 1's relative cost advantage in markets A and B, respectively. Due to the separation result, we have the following proposition.

Proposition 1. If two products are independently marketed, the lowest cost firm in each component market will be the highest bidder in the relevant market. The cost reduction (the winning bid) in each market, $\overset{*}{\Delta}_j$, is given by

$$\overset{*}{\Delta}_j = \begin{cases} \Delta(|\delta_j|), & \text{if } |\delta_j| < \overset{o}{\delta} \ (=\overset{o}{\pi}) \\ \overset{o}{\Delta}, & \text{if } |\delta_j| \geq \overset{o}{\delta} \ (=\overset{o}{\pi}) \end{cases}, \quad \text{where } j = A, B.$$

In other words, without bundling, the overall R&D pattern will replicate the R&D pattern that would occur if the markets were separate.

(ii)Bundling

To isolate the pure strategic effect of bundling on subsequent R&D competition, I have to ensure that the underlying R&D environments do not change with the decision to bundle. I fulfill this requirement by assuming that specific rules governing the auction in each market are the same as before. However, it will be shown that bundling changes the bidding behavior, resulting in different patterns of R&D.

With bundling, the deciding factor for market dominance is the overall production cost of the bundled products; the distributions of the production costs across components are irrelevant. Therefore, each firm will allocate its R&D resources across components so that the sum of cost-saving from each component is achieved at minimum cost. Consider a firm's R&D cost minimization problem of reducing the total production cost by Δ when the cost of innovation is given by $\Phi(.)$ for each component.

$$\min_{\Delta_A,\, \Delta_B} \ \Phi(\Delta_A) + \Phi(\Delta_B)$$

subject to

$$\Delta_A + \Delta_B = \Delta$$

The convexity of $\Phi(.)$ implies that R&D efficiency is attained when $\Delta_A = \Delta_B = \Delta/2$; if a firm would like to reduce the total production cost by Δ, it will do so by reducing the cost by $\Delta/2$ for each component. An efficient bidding strategy which minimizes the cost of bidding for a given sum of cost reduction in both markets (assuming that the firm wins auctions in both markets), therefore, requires that the bids in both markets be equal.[9]

With bundling, I will restrict each firm's bidding strategy to the efficient one. This assumption captures the idea that when what matters is total cost, R&D resources will be allocated efficiently.[10] It should be emphasized that any result that follows does not

[8]This is not necessarily true if we have a downward-sloping demand curve for the "system good." In this case, the demand for the good depends on the sum of the prices in each market. Therefore, the incentive for cost reduction in one market can depend on the price charged in the other market. In contrast, with rectangular demand assumed, there is no price effect on quantity demanded as long as the reservation value for the good V is sufficiently large. Monroe (1993), however, shows that when prices are constrained by costs (the low-cost firm's price in each market is equal to its competitor's cost) many of the results that are true when demand is inelastic remain true when demand is elastic. See Monroe (1993) for details.

[9]The assumption that the cost function for innovation (Φ) is the same across component products is not crucial for the paper. If I assumed that the cost of innovation is given by Φ_A and Φ_B for products A and B, respectively, efficiency requires that the marginal cost of cost reduction be equalized.

[10]Alternatively, I could assume that the rule of auction is that the winner is determined by the one who submits the highest total cost reduction. Then, the efficient bidding rule is endogenously derived. However, I should point out that the specification of the auction rule subsumes the physical characteristics of R&D if I interpret the auction as a snapshot of a dynamic game of adoption as explained before.

depend on the bidding rule imposed (see the Appendix).[11]

To analyze the outcome of auctions, without loss of generality, assume that δ_A (= $a_2 - a_1$) ≥ 0 and $\delta_A + \delta_B$ (= $[a_2 - a_1]+[b_2 - b_1]$) ≥ 0. The following proposition, then, characterizes the equilibrium in the R&D auction under bundling.

Proposition 2. Firm 1 outbids firm 2 in the R&D game in both markets and its winning bid, $\tilde{\Delta}^*_A=\tilde{\Delta}^*_B$, is given by[12]:

$$\tilde{\Delta}^*_A=\tilde{\Delta}^*_B=\begin{cases}\Delta(\frac{\delta_A+\delta_A}{2}), & \text{if } \delta_A+\delta_A<2\overset{o}{\delta} \\ \overset{o}{\Delta}, & \text{if } \delta_A+\delta_A\geq 2\overset{o}{\delta}\end{cases} \tag{8}$$

Therefore, we have efficiency in R&D if $\delta_A + \delta_B \geq 2\overset{o}{\delta}$. Otherwise, there will be excessive R&D due to competition. The net profit from bidding for firm 1 is given by:

$$\tilde{\pi}^*(\delta_A+\delta_B) = \begin{cases}\delta_A+\delta_B, & \text{if } \delta_A+\delta_B<2\overset{o}{\delta} \\ 2\overset{o}{\delta}, & \text{if } \delta_A+\delta_B\geq 2\overset{o}{\delta}\end{cases} \tag{9}$$

Proof. With the efficient bidding assumption, firm 2 which has the overall cost disadvantage of ($\delta_A + \delta_B$), is willing to bid in each market up to $\bar{\Delta}_A= \bar{\Delta}_B(=\bar{\Delta})$, where:

$$[\bar{\Delta}_A+\bar{\Delta}_B] - [\delta_A + \delta_B] - [\Phi(\bar{\Delta}_A) + \Phi(\bar{\Delta}_B)] = 0 \tag{10}$$

Dividing Eq. (10) by 2 and using the fact that $\bar{\Delta}_A= \bar{\Delta}_B$ with efficient bidding, I have

$$\bar{\Delta} - [\delta_A + \delta_B]/2 - \Phi(\bar{\Delta}) = 0 \tag{11}$$

Therefore, $\bar{\Delta} = \Delta(\frac{\delta_A+\delta_A}{2})$ if $\delta_A + \delta_B < 2\overset{o}{\delta}$ [see Eq. (2)]. Otherwise, there is no positive value of $\bar{\Delta}$ which satisfies Eq. (11), which implies that firm 2 bids zero in each market.

We can easily verify that firm 1 has a higher incentive to bid as in lemma 1, and the winning bid in each market is given by (8). The rest of the proof proceeds as in the discussion above lemma 1. Q.E.D.

[11]Without this assumption, I could have multiple equilibria. However, as will be clear later, the equilibrium selection among multiple equilibria do not alter any major conclusions.

[12]Variables corresponding to bundling are denoted with tilde.

IV. Market Equilibrium vs. Second-Best Bundling Decision

Having specified the nature of the R&D and the price decisions under bundling and nonbundling, I can now analyze the incentive to bundle. Note that bundling is a unilateral decision. In other words, for competition to occur under bundling, only one firm need have an incentive to bundle.[13] With the maintained assumption of $\delta_A+ \delta_B > 0$, firm 2 never has an incentive to initiate bundling. The reason is that with bundling, it will always have zero profit while it can have a positive profit in market B without bundling provided $\delta_B < 0$. I, therefore, turn my attention exclusively to firm 1's incentive to bundle. To analyze further, it is useful to distinguish two cases depending on the sign of δ_B.

(i) $\delta_B > 0$ (the Case of a Clear Winner)

With the maintained assumption of $\delta_A > 0$, firm 1 is called a "clear winner" by Farrell, Monroe, and Saloner (1994). Given the relative initial cost positions (δ_A, δ_B), let $\Pi_1(\delta_A, \delta_B)$ and $\tilde{\Pi}_1(\delta_A, \delta_B)$ denote the reduced-form overall equilibrium profit functions for firm 1 under unbundling and bundling, respectively. In the clear winner case, firm 1's profit under each regime can be written as:

$$\Pi_1(\delta_A, \delta_B) = [\delta_A + \pi^*(\delta_A)]+ [\delta_B + \pi^*(\delta_A)]$$

The expression in the first square bracket is the profit from market A, which comprises of initial cost advantage (δ_A) and additional benefit from winning in the R&D game ($\pi^*(\delta_A)$). The expression in the second square bracket, which corresponds to the profit from market B, can be interpreted in the same way. Since $\pi^*(\delta_i) = \min[\delta_i, \overset{o}{\delta}]$, i= A, B (see Eq. (7)), we can rewrite $\Pi_1(\delta_A, \delta_B)$ as:

[13]The effect of bundling is equivalent to that of incompatibility between components made by different manufacturers in that consumers are forced to buy the whole system from the same vendor. In this respect, I can reinterpret the incentive to bundle as (dis)incentives to achieve mix-and-match compatibility. Two cases, however, need to be considered for an analysis of the incentive to mix-and-match compatibility. In the first case, compatibility requires industry-wide consensus. This occurs if the firms have proprietary technologies that can be protected by intellectual property rights. The second case is where compatibility can be achieved unilaterally. This occurs if one firm can make its components compatible with its rival's via an adapter [see Katz and Shapiro (1985), Matutes and Regibeau (1988), Farrell and Saloner (1992)].

$$\Pi_1(\delta_A, \delta_B) = (\delta_A + \delta_B) + \min[\delta_A, \overset{o}{\delta}] + \min[\delta_B, \overset{o}{\delta}]$$

With bundling, firm 1's reduced-profit function is given by:

$$\tilde{\Pi}_1(\delta_A, \delta_B) = (\delta_A + \delta_B) + \tilde{\pi}^*(\delta_A + \delta_B)$$

$$= (\delta_A + \delta_B) + \min[\delta_A + \delta_B, 2\overset{o}{\delta}] \text{ (see Eq. (9))}$$

It can be easily verified that

$$\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) \geq 0$$

The equality holds when $\delta_A \leq \overset{o}{\delta}$, $\delta_B \leq \overset{o}{\delta}$ or $\delta_A \geq \overset{o}{\delta}$, $\delta_B \geq \overset{o}{\delta}$ holds. However, firm 1 strictly prefers bundling when $\delta_i > \overset{o}{\delta}$ and $\delta_j < \overset{o}{\delta}$, where i=A, B and i≠j. In this case, I can write $\delta_i = \overset{o}{\delta} + s_i$, where $s_i > 0$. Then, $\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = \min[\overset{o}{\delta} + s_i + \delta_j, 2\overset{o}{\delta}] - (\overset{o}{\delta} + \delta_j) = \min[s_i, \overset{o}{\delta} - \delta_j) > 0$.

I can interpret s_i as a slack in the preemptive R&D constraint in market i. Recall that if a firm's initial cost advantage exceeds the critical value $\overset{o}{\delta}$ there is no pressure to preempt its rival firm in R&D competition. In other words, the constraint for preemptive R&D is not binding and a firm can pace its R&D activities at the rent-maximizing rate. What bundling does, then, is basically to pool constraints for preemptive R&D in two markets. As a result, when $\delta_i > \overset{o}{\delta}$ and $\delta_j < \overset{o}{\delta}$, it is possible to shift (unused) slack in the nonbinding constraint for market i to the binding constraint for market j, thereby reducing rent dissipation in market j. I will later call this mechanism the "leverage" of monopoly power. Interpreted in this way, it is not surprising that bundling has no effect when both constraints are binding ($\delta_A \leq \overset{o}{\delta}$, $\delta_B \leq \overset{o}{\delta}$) or neither constraints are binding ($\delta_A \geq \overset{o}{\delta}$, $\delta_B \geq \overset{o}{\delta}$).

To analyze the welfare implications of bundling, I define social welfare as the sum of industry profits and consumer surplus. If a social planner has the power to control every aspect of firm behavior, unbundling is always weakly preferred by the social planner because there can be duplication of R&D efforts in the case of bundling when each firm has initial advantages in different markets. In this paper, I consider a planner with more limited power who can only dictate the choice of bundling; R&D decisions and pricing

decisions are left to the firms.

Let $W(\delta_A, \delta_B)$ and $\tilde{W}(\delta_A, \delta_B)$ respectively denote the social welfare under nonbundling and bundling given (δ_A, δ_B). Then, the change in social welfare with bundling is :

$$\tilde{W}(\delta_A, \delta_B) - W(\delta_A, \delta_B) = [\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B)] + [\tilde{\Pi}_2(\delta_A, \delta_B) - \Pi_2(\delta_A, \delta_B)]$$

$$+ \text{ Consumer Surplus Change}$$

In the case of a clear winner, bundling turns out to have no effect on firm 2's profit and consumer surplus. Firm 2 has no profits in either regime since it is inferior in both markets ($\Pi_2(\delta_A, \delta_B) = \tilde{\Pi}_2(\delta_A, \delta_B) = 0$). Consumers also get the same consumer surplus across regimes. The reason is that in both cases, consumers will pay the price of a_2+b_2, which is the overall production cost of firm 2. Therefore, in the clear winner case, we have $\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = \tilde{W}(\delta_A, \delta_B) - W(\delta_A, \delta_B)$; private incentives and social incentives coincide. Proposition 3 summarizes the private and social incentives of bundling in the case of a clear winner.

Proposition 3. If firm 1 is a clear winner, then it strictly prefers bundling when $\delta_i > \overset{o}{\delta}$ and $\delta_j < \overset{o}{\delta}$, where i=A, B and i≠j, whereas firm 2 and consumers are indifferent. Market equilibrium coincides with the socially optimal outcome [see Figure 2].

A few remarks regarding Proposition 3 are in order. First, in the absence of R&D competition, the standard result in the literature is that in the clear winner case, bundling has no effect on competition and welfare with two firms [see Farrell, Monroe, and Saloner (1994) and Choi (1993)]. However, in the presence of R&D, bundling can increase profits and social welfare by softening R&D competition that results in the reduction of rent dissipation.[14]

[14]With more than two firms, Farrell *et al.* (1994) show that the clear winner prefers closed organization (bundling) because it induces higher costs offered by the other firms jointly. This preference, however, is due to a price effect. Consequently, the effect of bundling is only on the distribution of welfare in the absence of nonprice competition. The aggregate welfare is invariant across bundling regimes, regardless of the number of firms in the

Second, the mechanism through which profit is increased due to bundling corresponds to the "leverage" of monopoly power from one market to the other. When $\delta_i > \overset{o}{\delta}$, the firm faces no competition in the R&D stage and behaves as a monopolist in market i. If components are separately marketed, the slack in that market, s_i, remains underutilized. Bundling provides a mechanism through which this underutilized monopoly power can be leveraged in the other market where rent is excessively dissipated due to preemptive R&D pressure. In the case of a clear winner, this leverage of monopoly power also enhances social welfare. Therefore, as the critics contend, bundling occurs for efficiency reasons. However, in the case of no clear winner, it will be demonstrated that the privately optimal "leverage" can be socially harmful.

Third, the mechanism through which "leverage" is generated is reminiscent of the one in Bernheim and Whinston (1990). They demonstrate how the pooling of the incentive constraints can facilitate collusion via multimarket contact; slack in the incentive constraint for collusion in one market can be used to facilitate collusion in the other market.[15]

Finally, it should be emphasized that the profit increase from bundling is *not* due to the efficient bidding rule imposed in the auction. Note that the efficient bidding rule was imposed both on the winning firm and the losing firm. As a result, any efficiency gain from the efficient bidding rule is exactly offset by more intensified bidding by the losing firm. Therefore, the gain from bundling is not from better coordination of the R&D budget *per se* which equalizes the marginal productivity of R&D across markets, but from the transfer of monopoly power from one market to another. This explains why the selection of the particular bidding rule under bundling will not alter the main result (as proved in the Appendix).

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industry.

[15]Bernheim and Whinston (1990) also prove the irrelevance result that when either the incentive constraints in both markets are satisfied individually (at the monopoly price) or neither is satisfied individually (at any price above cost), the pooling of incentive constraints does not help collusion.

(ii)$\delta_B < 0$ (the Case of Narrow Specialists)

This case is called "narrow specialists" by Farrell *et al.* (1994) since no firm is best at both activities. In this case, without bundling, firm 1 can earn profits only in market A while market B is captured by firm 2. Therefore, we have

$$\Pi_1(\delta_A, \delta_B) = \delta_A + \pi^*(\delta_A) = \delta_A + \min[\delta_A, \overset{o}{\delta}]$$

Under bundling, the profit function is the same as in the clear winner case.

$$\tilde{\Pi}_1(\delta_A, \delta_B) = (\delta_A + \delta_B) + \tilde{\pi}^*(\delta_A+\delta_B) = (\delta_A + \delta_B) + \min[\delta_A + \delta_B, 2\overset{o}{\delta}]$$

In contrast, in the case of narrow specialists, bundling also affects firm 2's profit and consumer surplus. Under nonbundling firm 2 will get positive profit in market B for which it holds an initial advantage, whereas it is foreclosed from the market and earns zero profit if firm 1 practices bundling.

$$\Pi_2(\delta_A, \delta_B) = |\delta_B| + \min[|\delta_B|, \overset{o}{\delta}]$$

$$\tilde{\Pi}_2(\delta_A, \delta_B) = 0$$

Consumers pay the price of $a_2 + b_1$ for the system without bundling. However, the system price under bundling will be a_2+b_2. Since $\delta_B = b_2 - b_1 < 0$ in the narrow specialists case, consumers get the additional consumer surplus of $|\delta_B|$ with bundling.

When firm 1 decides on bundling, it neglects the business stealing effect and consumer surplus gain [Mankiw and Whinston (1986)]. Note that the consumer welfare gain with bundling falls short of the profit loss of firm 2, i.e., $|\delta_B| < \Pi_2(\delta_A, \delta_B) - \tilde{\Pi}_2(\delta_A, \delta_B) = |\delta_B| + \min[|\delta_B|, \overset{o}{\delta}]$. Therefore,

$$\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = \tilde{W}(\delta_A, \delta_B) - W(\delta_A, \delta_B) + \min[|\delta_B|, \overset{o}{\delta}].$$

I conclude that the discrepancy between the consumer surplus effect and the business stealing effect causes excessive bundling from the social planner's viewpoint. When that occurs, we have a classical case of monopoly leverage which can be harmful for society.

Proposition 4. When a firm is a narrow specialist, there can be socially inefficient bundling. In this case, the business stealing effect dominates the consumer surplus effect [see Figure 2].

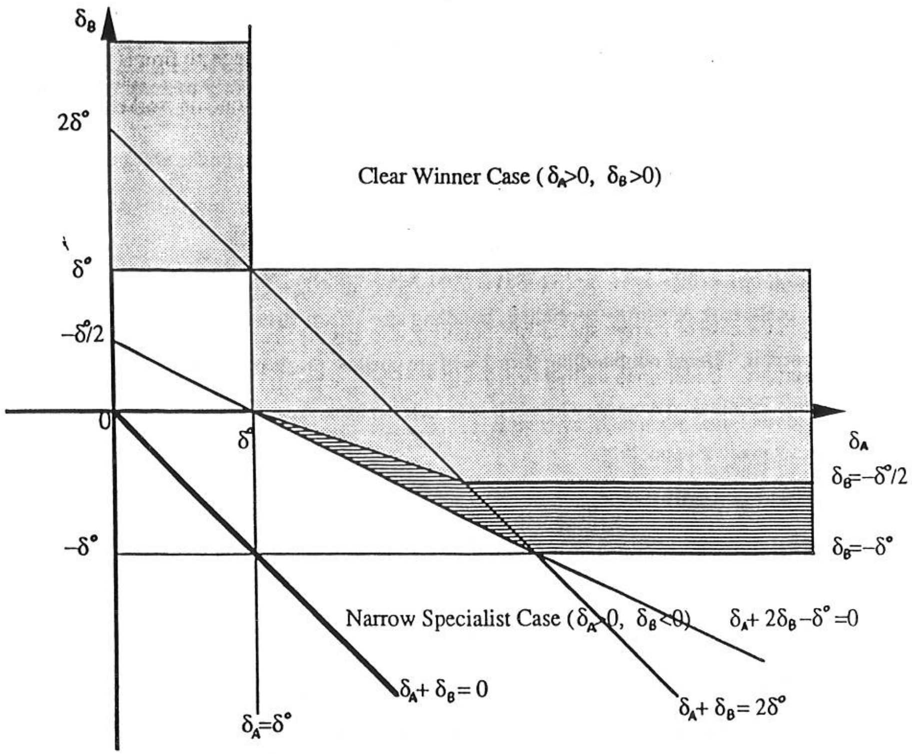

Figure 2. Market Equilibrium vs. Second-Best Social Optimum. The dotted area represents the region where bundling is privately and socially optimal while the horizontally-hatched area is the one where bundling is privately optimal but socially inefficient.

Figure 2, which compares the second-best bundling configuration with the market outcome, illustrates the possibility of socially inefficient bundling. In drawing Figure 2, I have made use of the assumption that $\delta_A \geq 0$ and $\delta_A + \delta_B \geq 0$. The same type of analysis can be applied symmetrically to other cases.

To further analyze the incentive for firm 1 to bundle, I write

$$\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = \delta_B + \{\min[\delta_A + \delta_B,\ 2\delta^{o}] - \min[\delta_A,\ \delta^{o}]\}$$

Note that the first expression (δ_B) is negative and represents the adverse effect of bundling due to intensified competition. The expression in the bracket is the effect of bundling on R&D competition and can take either sign. If the latter effect is positive and dominates the first in absolute magnitude, bundling will be profitable for firm 1.

Proposition 5. In the case of narrow specialists, a necessary condition for firm 1 to engage in bundling is that $\delta_A > \delta^{o}$ and $\delta_B > -\delta^{o}$.

Proof. If $\delta_A \leq \delta^{o}$, we have

$$\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = \delta_B + \{\min[\delta_A + \delta_B,\ 2\delta^{o}] - \delta_A\}$$
$$\leq \delta_B + \{[\delta_A + \delta_B] - \delta_A\} = 2\delta_B \leq 0.$$

Therefore, bundling is not profitable if $\delta_A \leq \delta^{o}$. Now suppose that $\delta_A > \delta^{o}$ but $\delta_B \leq -\delta^{o}$. Then, we have

$$\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = \delta_B + \{\min[\delta_A + \delta_B,\ 2\delta^{o}] - \delta^{o}\}$$
$$\leq \delta_B + \{2\delta^{o} - \delta^{o}\} = \delta_B + \delta^{o} \leq 0.$$

This implies that $\delta_A > \delta^{o}$ and $\delta_B > -\delta^{o}$ is a necessary condition for bundling to be profitable. Q.E.D.

Proposition 5 once again makes it clear that for bundling to be profitable for firm 1 there must be slack in the preemption constraint ($\delta_A > \delta^{o}$) for the tying good market (A) while the constraint for the tied good market (B) must bind for firm 2 ($|\delta_B| < \delta^{o}$).

The model also formalizes Kaplow's (1985) contention that the criticisms of the leverage theory are "wholly beside the point" since they attempt to disprove the existence of the *long-term* leverage effect by using *static* analysis. If I interpret the R&D bidding game as a snapshot of dynamic R&D competition that takes place over time (as will be done in the next section), the analysis makes explicit the tradeoffs between the dynamic gain and static loss involved in the bundling decision. Thus, I can make a distinction "between effects that can be observed in a static model and effects that only emerge from a dynamic perspective [Kaplow (1985)]." Consistent with the critics, the static effect of bundling is negative due to intensified price competition ($\delta_B<0$), which makes bundling unattractive for the purpose of monopolization. However, a consideration of the dynamic effects of bundling through R&D competition can outweigh its immediate impact.[16]

IV. A Dynamic Formulation

In the previous section, I demonstrated the possibility of monopoly power leverage in a simple static model of R&D bidding. The simplified bidding model captures the idea that the firm with the initial advantage has more incentive to engage in R&D to maintain its superior position as in Gilbert and Newbery (1982). One crucial assumption in the bidding model, however, was that the losing firm did not forego its bid. In this section, this assumption is justified by considering the innovation adoption process as a simple timing game in a dynamic context. With R&D competition modeled as preemptive technology adoption, it is natural to assume that the loser (preempted firm) does not incur any adoption costs if a later adoption is not worthwhile. This is true in the case of Bertrand competition.

Suppose that there is an innovation that reduces each firm's unit cost by Δ in each market. The assumption of symmetric R&D opportunities across markets is made for the sake of simplicity and is not crucial for the main results. The profit is discounted at the rate of r. Let $\Phi(t)$ be the cost of adopting the technology at time t in time zero dollars. Following Katz and Shapiro (1987) and Fudenberg and Tirole (1987), I assume that $d(\Phi(t)e^{rt})/dt<0$ and $d^2(\Phi(t)e^{rt})/dt^2>0$. The assumption says that the current cost of innovation adoption declines over time, but at a decreasing rate. To ensure an interior solution, further assume that $\Phi(0)$ is sufficiently large so that no one adopts at time zero and that $\Phi(t)e^{rt}\to 0$ as $t\to\infty$.

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[16]Kaplow (1985) listed four reasons why past analysis of the leverage possibility is deficient: (i) the failure to note the minimal cost of monopolistic practices, (ii) the use of static models, (iii) the neglect of the free rider problem, and (iv) the tendency to assume perfect markets. It can be said that, whereas Whinston (1990) addressed the fourth aspect of Kaplow's critique, this paper addresses the second one.

If there is no bundling, I can analyze the two markets separately as before. Once again, assume that $a_1\le a_2$ without loss of generality. Suppose that firm 2's relative cost disadvantage in market A, δ_A ($=a_2-a_1$), is less than the size of innovation Δ. Then, firm 2's profit in market A when it is the first one to adopt at time T is given by:

$$\pi(T,\delta_A)=\int_T^\infty(\Delta-\delta_A)\,e^{-rt}dt-\Phi(T)$$

Let us define $T(\delta_A)$ as a T which solves the relationship $\pi(T,\delta_A)=0$, i.e.,

$$(\Delta-\delta_A)/r=\Phi(T)e^{rT},\ \text{if } (\Delta-\delta_A)>0.$$

Then, the earliest time that firm 2 is willing to adopt the innovation assuming that neither one has yet adopted, $\overline{T_2}$, is given by $T(\delta_A)$ if $\delta_A<\Delta$.[17] Otherwise, there is no T which satisfies $\pi(T,\delta_A)=0$. In this case, we set $\overline{T_2}=\infty$.

As in the case of bidding, it can be easily verified that the earliest date firm 1 is willing to preempt in technology adoption is before $\overline{T_2}$. Let me define T^o as the rent-maximizing adoption time for firm 1:[18]

$$T^o=\underset{t}{\operatorname{argmax}}\int_t^\infty\Delta\,e^{-rt}dt-\Phi(t)$$

Then, firm 1 is the first one to adopt the innovation and its equilibrium adoption time, T_A^*, is the earlier of $\overline{T_2}$ and T^o. Note that $\overline{T_2}=T(\delta_A)$ is strictly increasing in δ_A if $\delta_A<\Delta$ and that $\overline{T_2}=\infty$ if $\delta_A\ge\Delta$. This implies that there is a unique value δ^o ($<\Delta$) at which $\overline{T_2}=T^o$.

Therefore, T_A^* can be written as:

$$T_A^*=\begin{cases}T_2(\delta_A), & \text{if } \delta_A<\delta^o\\ T^o, & \text{if } \delta_A\ge\delta^o\end{cases}$$

Profit for firm 1 in market A is:

$$\Pi_1(\delta_A)=\int_0^{T_A^*}\delta_A\,e^{-rt}dt+\int_{T_A^*}^\infty(\delta_A+\Delta)\,e^{-rt}dt-\Phi(T_A^*)$$

Firm 2 has no profit in market A. Market B can be analyzed in a similar way.

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[17]Such a date is called the "earliest preemption date'" by Katz and Shapiro (1986).
[18]Katz and Shapiro (1986) call T^o the "stand alone date" of adoption.

Now suppose that the two products are bundled. Analyzing this case in full generality is not difficult conceptually. However, it requires consideration of many sub-cases, depending on the relative magnitudes of δ_A, δ_B, $\overset{o}{\delta}$, and Δ. Since the complete characterization of the R&D game *per se* is not the main purpose of the paper, I will be content only to demonstrate the possibility of "leverage", which is privately optimal but socially undesirable. For that purpose, consider an extreme case of the narrow specialists ($\delta_A > 0$, $\delta_B < 0$) with $\delta_A + \delta_B > 2\Delta$, which ensures that firm 2 will never adopt any innovation with bundling.[19] Therefore, firm 1 will adopt both innovations at time T^o. Firm 1's profit with bundling is:

$$\tilde{\Pi}_1(\delta_A, \delta_B) = \int_0^{T^o} (\delta_A+\delta_B)\, e^{-rt}dt + \int_{T^o}^{\infty} (\delta_A+\delta_B+2\Delta)\, e^{-rt}dt - 2\Phi(T^o)$$

Without bundling, firm 1 can get positive profits only in market A:

$$\Pi_1(\delta_A, \delta_B) = \int_0^{T^o} \delta_A\, e^{-rt}dt + \int_{T^o}^{\infty} (\delta_A+\Delta)\, e^{-rt}dt - \Phi(T^o)$$

Therefore, firm 1 will engineer bundling if the following condition holds:

$$\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B) = -\int_0^{\infty} |\delta_B|\, e^{-rt}dt + \int_{T^o}^{\infty} \Delta\, e^{-rt}dt - \Phi(T^o) > 0$$

I can interpret the first integral as the loss from intensified competition (note that δ_B is negative). The second term represents rent extraction from R&D in market B which became available due to the leverage of monopoly power in market A.

The effect of bundling on firm 2 is its loss of profit in market B attainable under nonbundling:

$$\tilde{\Pi}_2(\delta_A, \delta_B) - \Pi_2(\delta_A, \delta_B) = -\left[\int_0^{T_B^*} |\delta_B|\, e^{-rt}dt + \int_{T_B^*}^{\infty} (|\delta_B|+\Delta)\, e^{-rt}dt - \Phi(T_B^*)\right]$$

[19]It should be mentioned that, in order to expedite presentation, I imposed a much stronger parameter restriction ($\delta_A+\delta_B>2\Delta$) than actually needed. Therefore, the extremity of the parametric assumption should not be used as a criticism of the discussion that follows.

Consumers gain with bundling due to a lower system price (a_2+b_2 instead of a_2+b_1) caused by intensified competition:

$$\text{Change in Consumer Surplus} = \int_0^{\infty} |\delta_B|\, e^{-rt}dt$$

The change in social welfare with bundling is given by:

$$\tilde{W}(\delta_A, \delta_B) - W(\delta_A, \delta_B) = [\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B)] + [\tilde{\Pi}_2(\delta_A, \delta_B) - \Pi_2(\delta_A, \delta_B)]$$
$$+ \text{Consumer Surplus Change}$$
$$= [(\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B)] - [\int_{T_B^*}^{\infty} \Delta\, e^{-rt}dt - \Phi(T_B^*)]$$
$$\leq [(\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B)]$$

Therefore, once again, we can conclude that there is an excessive private incentive for bundling compared with the social optimum.

More precisely, at $\delta_B=0$ we have $[\int_{T_B^*}^{\infty} \Delta\, e^{-rt}dt - \Phi(T_B^*)]=0$; monopoly rent in market B is completely dissipated with identical costs. Therefore, we have $[\tilde{W}(\delta_A, 0) - W(\delta_A, 0)] = [\tilde{\Pi}_1(\delta_A, 0) - \Pi_1(\delta_A, 0)] > 0$. Note that $[\tilde{W}(\delta_A, \delta_B) - W(\delta_A, \delta_B)]$ and $[\tilde{\Pi}_1(\delta_A, \delta_B) - \Pi_1(\delta_A, \delta_B)]$ are decreasing in $|\delta_B|$ for $\delta_B < 0$. Moreover, it can be verified that $[\tilde{W}(\delta_A, -\overset{o}{\delta}) - W(\delta_A, -\overset{o}{\delta})] < [\tilde{\Pi}_1(\delta_A, -\overset{o}{\delta}) - \Pi_1(\delta_A, -\overset{o}{\delta})] < 0$. Therefore, an interval $(-\overset{o}{\delta}, 0)$ contains unique values, $\delta_B{}^*$ and $\delta_B{}^{**}$, such that $[\tilde{W}(\delta_A, \delta_B{}^*) - W(\delta_A, \delta_B{}^*)] = [\tilde{\Pi}_1(\delta_A, \delta_B{}^{**}) - \Pi_1(\delta_A, \delta_B{}^{**})] = 0$. Since $\frac{\partial[\tilde{W} - W]}{\partial \delta_B} > \frac{\partial[\tilde{\Pi}_1 - \Pi_1]}{\partial \delta_B}$ for $\delta_B < 0$, we have $-\overset{o}{\delta} < \delta_B{}^{**} < \delta_B{}^* < 0$. Consequently, we can conclude that for any δ_B such that $\delta_B{}^{**} < \delta_B < \delta_B{}^*$, bundling is privately optimal but socially harmful [see Figure 3].

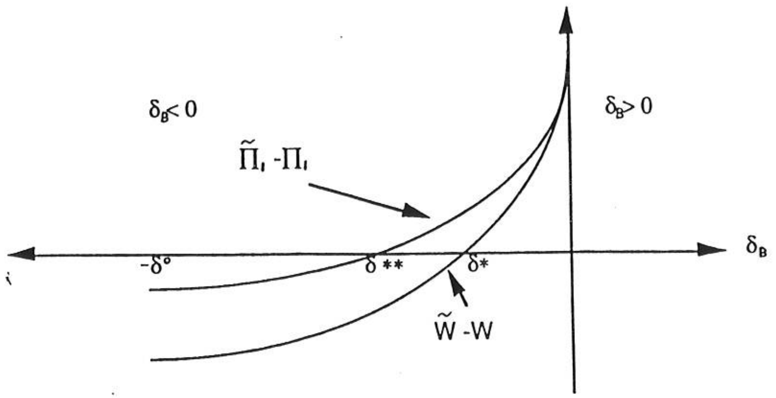

Figure 3. Private vs. Social Incentives for Bundling in a Dynamic Framework.

V. Conclusion

This paper shows that the exclusivity of attention on price competition in the analysis of bundling can be misleading.[20] I reexamine the possibility of leveraging monopoly power in a stylized model of R&D competition. After confirming the impossibility result of the Chicago school in a simple price competition model, the paper demonstrates how adding R&D competition can make bundling a profitable commitment device. Bundling is used as a mechanism to shift underutilized monopoly "slack" in one market to another market where the rent-dissipation constraint is binding. When the beneficial effect of this cross utilization of monopoly power is sufficiently large to offset the negative effect of intensified price competition, bundling can be a profitable strategy.

To analyze the welfare implications of bundling, I distinguished two cases: a "clear winner" case and "narrow specialists" case. In the clear winner case, private incentives and social incentives coincide and bundling is always efficiency-enhancing as the critics argue. However, in the narrow specialists case, the possibility of welfare-reducing, but privately optimal bundling is demonstrated. This result implies that more scrutiny of bundling from antitrust authorities is warranted.

I can also reinterpret the results of this paper in the framework of mix-and -match compatibility decisions since bundling is equivalent to incompatibility between components made by different manufacturers.[21] With this interpretation, the process through which compatibility is achieved must be specified. If I assume that compatibility requires adoption of a common standard and consequently can be achieved only with the agreement of all firms, the analysis in the paper will be applied without any modification since incompatibility can be imposed unilaterally. With this interpretation, my results are in sharp contrast to Matutes and Regibeau (forthcoming). After conceding that not much is known about the link between compatibility and R&D in mix-and-match models, they conjecture that "the firms' incentive to invest in R&D would be greater when their components are incompatible with those of their rival." The reason behind their conjecture is that "incompatible firms would capture the whole benefit of their own cost saving while the efforts of compatible firms would also help the sale of 'mixed' systems which include one of their rival's components." The model in this paper, however, points out that if the nature of R&D is preemptive, the comparison of relative R&D expenditures could easily run in the opposite direction.[22]

If compatibility can be achieved unilaterally via converters, then, in the case of

[20] As argued by Posner (1976), without any non-price competition, the leverage of monopoly power is impossible. The reason is that the market price is always constrained by the rival firm's costs or the demand function. With price competition there can be no slack even in the monopolized market. Consequently, any profit increase in the other market due to leverage should be accompanied by a corresponding loss in the monopolized market.

[21] The connection between product tying and manipulation of interface standards has also been recognized by David and Greenstein (1990).

[22] Matutes and Regibeau's (1994) conjecture may not hold up even in their own framework because they do not consider the strategic effect of R&D on the subsequent price competition in their discussion. Since entry and exit are not an issue in their model, firms will adopt a puppy-dog strategy to soften price competition [Fudenberg and Tirole (1984)]. Since incompatibility induces more intense price competition [Matutes and Regibeau (1988)], the incentive to soften price competition with a lower R&D will be greater with incompatibility, which has countervailing effects on the R&D incentives identified by them.

narrow specialists, the firm with a higher overall production cost will have an incentive to enforce compatibility by building a converter. In this case, we can eliminate socially inefficient incompatibility. However, socially efficient incompatibility will be eliminated, too.[23] Interpreted in the context of mix-and-match compatibility, this paper provides a useful framework for analyzing R&D incentives in "systems markets." There has been little work in this area with the exception of Monroe (1993).

Finally, it would be worthwhile to learn whether the intuition garnered in this paper can be extended to forms of nonprice competition other than R&D such as advertising [Tauber (1988)].

[23] I ignore the issue of product differentiation which has the socially beneficial effect of demand-enhancing as in Matutes and Regibeau (1988).

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Appendix

In this appendix, I demonstrate that the main results in the paper do not rely on the assumption of the efficient bidding rule in the case of bundling.

First, I observe that if $\delta_A + \delta_B \geq 2\overset{o}{\delta}$, it is not worthwhile for firm 2 to participate in the bidding. Therefore, the choice of bidding rule has no meaning in this case; firm 1 achieves efficiency in R&D by bidding $\overset{o}{\Delta}$ in each market and its rent $(\tilde{\pi}^*(\delta_A+\delta_B))$ is maximized at $2\overset{o}{\delta}$.

If $\delta_A + \delta_B < 2\overset{o}{\delta}$, without restricting firm 2's bidding strategy to the efficient one, the locus of maximum bids firm 2 is willing to make in each market $(\bar{\Delta}_A, \bar{\Delta}_B)$ is given by Eq. (10) in the main text:

$$[\bar{\Delta}_A+\bar{\Delta}_B] - [\delta_A + \delta_B] - [\Phi(\bar{\Delta}_A) + \Phi(\bar{\Delta}_B)] = 0 \qquad (10)$$

Due to the convexity of Φ, the *maximum bidding frontier* for firm 2 (MBF_2) is concave [see Figure A-1]. The exact location of MBF_2 will depend on the magnitude of $(\delta_A + \delta_B)$; the smaller the $(\delta_A + \delta_B)$ is, the further out from the origin the MBF_2 is located. Note that firm 2' maximum willingness to bid in each market cannot be lower than the rent-maximizing level $\overset{o}{\Delta}$. Firm 2's maximum willingness to bid in one market is maximized when it bids $\overset{o}{\Delta}$ and generates the maximum rent $(\overset{o}{\delta})$ in the other market. In that case, the maximum bid firm 2 can make in one market is the highest Δ such that

$$(\Delta - [\delta_A + \delta_B] + \overset{o}{\Delta}) - \Phi(\Delta)= 0$$

Therefore, the intercepts of MBF_2 are given by $\Delta([\delta_A + \delta_B] - \overset{o}{\Delta})$. See Eq.(2) for the definition of $\Delta(.)$.

Similarly, I can draw MBF_1, which lies above MBF_2. This implies that firm 1 will always outbid firm 2 in each market. Without the assumption of the efficient bidding rule (i.e., $\bar{\Delta}_A=\bar{\Delta}_B$) we have multiple equilibria since any point $(\bar{\Delta}_A, \bar{\Delta}_B)$ on MBF_2 can represent an equilibrium bid. However, all these points (including the efficient one) generate the same rents for firm 1.

$$\tilde{\pi}^*(\delta_A+\delta_B) =[\bar{\Delta}_A+\bar{\Delta}_B] - [\Phi(\bar{\Delta}_A) + \Phi(\bar{\Delta}_B)] = \delta_A + \delta_B \qquad \text{[see Eq. (10)]}$$

Therefore, the equilibrium payoff for firm 1 is independent of the choice of the bidding strategy and the equilibrium resulting from it.

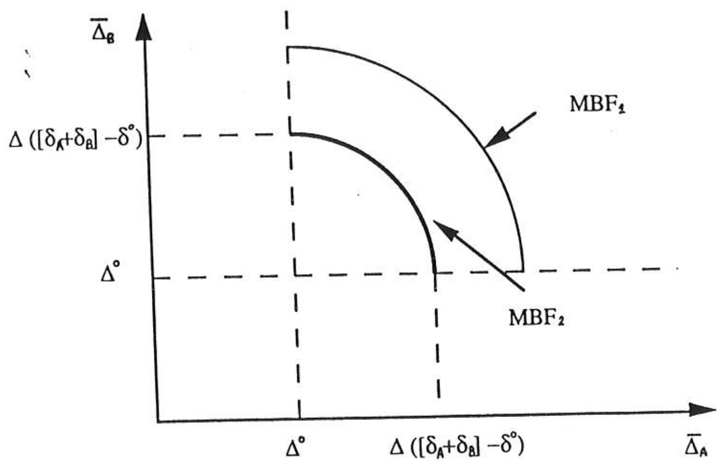

Figure A-1: Bidding Equilibria under Bundling without the Assumption of the Efficient Bidding Rule. The figure is drawn for a particular level of $[\delta_A + \delta_B]$, where $0 < \delta_A + \delta_B < 2\delta^{o}$.

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