**Tying and Innovation:
A Dynamic Analysis of Tying Arrangements**

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Abstract

This paper analyzes the effects of tying arrangements on R&D incentives. It shows that tying is a means through which a firm can commit to more aggressive R&D investment in the tied goods market. Tying also has the strategic effect of reducing rivals' incentives to invest in R&D. The strategy of tying is a profitable one if the gains, via an increased share of dynamic rents in the tied goods market, exceed the losses that result from intensified price competition in the market. The welfare implications of tying, and consequently the appropriate antitrust policy, are shown to depend on the nature of R&D competition. (*JEL* L13, L41, O31)

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I. Introduction

This paper investigates the effects of tying arrangements on incentives to innovate. The analysis is particularly relevant in light of the recent antitrust case involving Microsoft. Specifically, it has been alleged that Microsoft's decision to integrate its Internet browser program, Internet Explorer, with its operating system software, Windows 95, allows Microsoft to leverage its monopoly power in the operating system market into the Internet browser market. What distinguishes the Microsoft case from previous antitrust cases concerning tying arrangements is that its focus is predominantly on the effects of tying on innovation. Microsoft's competitors, particularly Netscape, argue that Microsoft's tying practices lock customers into a single monolithic program and stifle innovation in the industry. Microsoft, in response, contends that the real threat to innovation would come from Government intervention to stop it from bundling products, like a browser, into its Windows operating system. Joel Klein, the Assistant Attorney General in charge of the Justice Department's antitrust division, states that mission of the antitrust authorities in the Microsoft case is to "create circumstances in which the right innovation signals are given" (Labaton, 1997). Though the parties involved do not agree on much, all acknowledge that innovation is a key issue in this debate.

In light of this, it is unfortunate that most existing studies on tying arrangements focus exclusively on static price competition, and thus are not adequate to analyze the case. Perhaps more importantly, it is unclear whether the nation's antitrust policy--which was developed in the late nineteenth and early twentieth centuries to address concerns about price practices in the railroad and smokestack industries--is appropriate in the context of the rapidly evolving technology based industries like computing and the Internet (Lohr, 1998). Traditionally, the focus of the nation's antitrust policy has been to look for the evidence of raising prices by a dominant company. In the information industries, however, there is scant evidence of monopolistic abuse in price in that prices

in the information industries have been falling by any means even without adjusting for performance improvements. Considering the central role innovation plays in these industries, the focus of antitrust enforcement should be rather in ensuring that there is a competitive market for innovation. Thus, basing the nation's antitrust policy narrowly on the price practices can result in misguided antitrust enforcement.¹

In this paper, I attempt to fill this gap by providing a framework through which the effects of tying on R&D incentives, and welfare implications thereof, can be analyzed. Specifically, I extend Whinston's (1991) theory of tying and foreclosure by allowing for the possibility of R&D investments that precede the price game.

The paper proceeds as follows. In Section II, I briefly review the leverage theory of tying and extensions. To highlight the importance of innovation to my story, in Section III, I develop a simple model of tying without R&D competition. I illustrate that tying arrangements intensify price competition and can only reduce the profit of the tying firm: even though bundling allows the tying firm to "steal business" from the rival firm, the cost of it does not justify the practice. This confirms the Chicago school's central contention that tying cannot be used for the purpose of leveraging monopoly power (see Bowman 1957, Posner 1976, and Bork 1978) and highlights the importance of considering the innovation game in the analysis of tying. Section IV extends the basic model by allowing for R&D competition. It shows that tying can serve as a mechanism for the tying firm to commit itself to more aggressive R&D in the tied good market. This commitment also has the strategic effect of dulling the R&D incentives of rival firms. In Section V, I analyze an explicit example of R&D competition to derive closed form solutions. I show that the dynamic gains from bundling can outweigh the static losses:

¹ Baumol and Ordover (1992) suggest that "the main source of the problem is the fact that the design of defensible antitrust policy for dynamic industries, meaning industries in which product and process innovation constitute key market strategies, raises significant methodological difficulties. These difficulties arise precisely because, when narrowly perceived, antitrust policies seem too much preoccupied with static market power and competition at the expense of dynamic considerations."

that is, when R&D competition is introduced, bundling can be profitable. I also consider the welfare impact of tying and antitrust implications. Concluding remarks follow in Section VI.

II. The Leverage Theory of Tying and Extensions

According to the "leverage theory" of tying, a multiproduct firm with monopoly power in one market can monopolize a second market using the leverage provided by its monopoly power in the first market. The leverage theory has been the key intellectual rationale for the historically harsh treatment of tying arrangements by the courts.² Recently, however, the leverage theory had come under attack and become largely discredited as a result of criticisms originating in the Chicago School (see e.g. Bowman 1957, Posner 1976, Bork 1978).³ As a result, price discrimination, as opposed to leverage, has come to be seen as the main motivation for tying (Stigler 1956, Adams and Yellen 1976, McAfee, McMillan, and Whinston 1986).

Recently, however, Whinston (1990) has revived the leverage theory of tying. He shows that if the market structure in the tied good market is oligopolistic, and in the presence of scale economies, tying can be an effective and profitable strategy to alter market structure by making continued operation unprofitable for tied good rivals. Previous models of tying missed this "strategic effect" due to their adherence to the assumption of competitive, constant returns-to-scale structure in the tied good market. It is important to keep in mind, however, that in Whinston's basic model, inducing the exit of the rival firm is essential for the profitability of tying arrangements.⁴ Thus, if the

² The leading case is *Motion Pictures Patents Co. v. Universal Film Manufacturing Co.*, 243 U.S. 502 (1917). Other cases include *International Salt v. U.S.*, 332 U.S. 392 (1947) and *Northern Pacific Railway Co. v. U.S.*, 356 U.S. 1 (1958).

³ 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.

⁴ Whinston (1990) points out that if the heterogeneity of consumer preferences are allowed for the tying good, tying can also serve as a price discriminating device and exclusion of the rival firm is not necessary for the profitability of tying. See also Carbajo et al. (1990).

competitor has already paid the sunk cost of entry and there is no avoidable fixed cost, tying cannot be a profitable strategy.

By contrast, the model I develop below demonstrates that even in the absence of exit by the rival firm, tying can be a profitable strategy via its long-term effects on competition through innovation. Thus, my analysis lends credence to Kaplow's (1985) contention that the traditional 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.

To highlight the importance of considering R&D competition, I first construct a model with only price competition. As shown in Whinston (1990), bundling induces the tying firm to engage in a more aggressive pricing strategy. The reason is that the tying firm can reap the benefits of selling its monopolized product only in conjunction with the sales of competitively supplied product. As a result, the tying firm will have a larger market share and take sales away from its competitors in the tied good market. Nonetheless, as discussed above, bundling is *not* profitable for the tying firm unless this strategic foreclosure induces *exit* by the rival firms because the tying firm's aggressive pricing induces the rival firms to respond by lowering their own prices.

When the possibility of R&D competition is considered, however, I show that the profitability of tying can be established through its effect on R&D incentives. The increased market share in the tied good market due to bundling is not a profitable strategy in itself. However, bundling also affects R&D competition. The tying firm's R&D incentives in the tied good market increase since it can spread out the costs of R&D over a larger number of units, whereas the rival firms' R&D incentives decrease. If this positive effect via R&D competition dominates the negative effect via price competition, tying can be beneficial for the tying firm even in the *absence* of exit by the rival firms

In a previous paper (Choi 1996), I extended the leverage theory to consider the impact of tying on the pace of innovation. In particular, I considered the effect of

bundling on R&D incentives in “systems” markets where two *complementary* products are to be used on a one-to-one basis. Using a model of *preemptive* innovation, I showed that bundling creates interdependence between constituent markets, thereby turning the two separate R&D games over components into a single one over the system. This allows the tying firm to utilize the unused monopoly slack in one R&D market to bolster its strategic position in the other R&D market.

In the present paper, I analyze *independent* products and consider more general specifications of R&D. More importantly, I focus on the interaction between the price game and the R&D game, rather than the interaction between the R&D games for the two products. Thus, the paper illustrates another innovation-related channel through which a firm can leverage the monopoly power in one market to gain advantage in another.⁵

III. Tying in the Absence of R&D Competition

Consider two independent products, A and B. They are unrelated in the sense that they can be consumed independently and their values to consumers are independent of whether they are consumed separately or together.⁶ Consumers, whose total measure is normalized to 1, are assumed to be identical and have a unit demand for each product valued at v_A and v_B , respectively. To focus on the strategic motive for bundling, I

⁵ In a related model, Farrell and Katz (1998) analyze how compatibility standards shape the nature of innovation and price competition in the presence of network effects. To the extent that compatibility can be unilaterally blocked through proprietary interface standards, the compatibility choice has similar effects to the tying decision in preventing other firms from supplying compatible complementary products. As in this paper, the consideration of R&D incentives is central to firms' compatibility choices. However, the focus of their paper is rather different from this paper. As is well known in the network externality literature (Katz and Shapiro, 1985; Farrell and Saloner, 1986), the existence of positive feedback generates multiple market equilibria and which equilibrium is selected in the market place crucially depends on expectations. Thus, Farrell and Katz's main emphasis is on how innovation in networks markets depend sensitively on the nature of consumers' and complementary product suppliers' expectations and how public policies can be used to influence these expectations to improve market performance.

⁶ In the Microsoft case, the relationship between the operating system and Internet browser program is unclear. At the first blush, they seem to constitute *complementary* products that form a system. As a technical matter, however, an Internet browser program might some day serve as a *substitute* operating system – a platform on which other applications program run – and could eliminate the importance of Windows. This future threat is believed to be a main reason why Microsoft is so keen on the Internet browser market. For an analysis of tying in systems markets, see Choi (1996).

assume that there is no cost advantage or disadvantage associated with bundling. The market for product A is monopolized by firm 1 with unit production cost of c_A ($< v_A$). It is assumed that entry to market A is not feasible. Firm 1 may have a patent or have an installed base that makes entry unprofitable in the presence of network externalities (Farrell and Saloner, 1986). The market for product B, however, is served by two firms, firm 1 and firm 2, who engage in Bertrand competition. For simplicity, product B is assumed to be homogeneous. Their unit production costs for product B are given by c_{B1} and c_{B2} for firm 1 and firm 2, respectively. Both firms are already in the market and have paid sunk cost of entry, if there is any. Thus, in contrast to Whinston (1990), entry and exit are *not* issues in this model.⁷

In such a case of no exclusion of the rival firm, tying is always a weakly dominated strategy if the production cost of each firm is given and cannot be altered.⁸ To see this, I consider the following two-stage game.

In the first stage, firm 1 (the monopolistic supplier of product A) 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.⁹

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 the bundling

⁷ If the two products are complementary components used in fixed proportions to comprise a system, firm 1 is trivially able to exclude firm 2 by bundling. However, Whinston (1990) shows that firm 1 never finds it worthwhile to bundle in order to monopolize market B.

⁸ This result also holds for the case of complementary products. See Choi (1996) and Farrell et al. (1998).

⁹ The precommitment to tying is plausible in the context of the Microsoft case if we believe Microsoft's claim that its operating system and web browser program are so integrated that the browser, Internet Explorer, cannot be removed without disabling the operating system, Windows.). The reason is that when Microsoft upgraded Internet Explorer to version 3.0, it placed some of the program's improved code into files that also contained instructions for operating system functions. The sharing of these files, called dynamic linked libraries, in the design of software makes these two programs difficult to separate without jeopardizing the stability of each program. For example, in a recent court filing, Microsoft argued that in the newly released Windows 98 operating system, Internet Explorer is so tightly integrated that it would "take many months (if not years) to develop and test" the operating system without the browser and until then the product "would be of no commercial value" (The NY Times, May 22, 1998).

decision through product design is a longer term decision that cannot be modified easily compared to the price decision. The outcomes are described below and depend on each firm's bundling decision in the first stage.

1. No Bundling

If the two products are not bundled, they can be analyzed independently. With the assumption of identical consumers and rectangular demand, firm 1 can extract the whole consumer surplus in market A and have profits of $(v_A - c_A)$. In market B, the low cost producer serves the whole market at the price of $\max(c_{B1}, c_{B2})$. Thus, firm 1 will have the profit of $\max[c_{B2} - c_{B1}, 0]$ in market B. Thus, the overall profit for the monopolist is given by

$$\Pi_1 = (v_A - c_A) + \max[c_{B2} - c_{B1}, 0] \quad (1)$$

2. Bundling

Suppose that the monopolist bundles product A and B and charges the price of P for the bundled product. In this case, consumers have two choices. The first option is to buy the bundled product from the monopolist at the price of P and the second one is to buy only product B from firm 2. For the first option to be chosen by the consumers, P should satisfy the following condition:

$$v_A + v_B - P \geq v_B - c_{B2} \quad (2)$$

This implies that the maximum price the tying firm can charge for the bundled product is given by $P = v_A + c_{B2}$. Firm 1's profit selling at that price is given by $(v_A + c_{B2}) - (c_A + c_{B1}) = (v_A - c_A) + (c_{B2} - c_{B1})$. Thus, firm 1's profit with bundling is given by

$$\tilde{\Pi}_1 = \max[(v_A - c_A) + (c_{B2} - c_{B1}), 0] \quad (3)$$

Thus, $\tilde{\Pi}_1 < \Pi_1$ unless firm 1 has cost advantages in market B, in which case it can be verified that bundling has no effect ($\tilde{\Pi}_1 = \Pi_1$).¹⁰ This implies that firm 1 never has the incentive to bundle for the purpose of monopolizing the tied good market, confirming the

¹⁰ Variables corresponding to bundling are denoted by a tilde.

critics of the leverage theory of tying.

Let $s_A = v_A - c_A (>0)$ denote the monopoly surplus in market A. One way to interpret the result above is that after bundling firm 1 behaves as if its cost of B were $c_{B1} - s_A$. The reason is that after bundling firm 1 can realize the monopoly surplus of s_A only in conjunction with the sale of product B. Thus, the firm is willing to sell product B up to the loss of s_A . This implies that firm 1 will price more aggressively after bundling and captures a larger market share in market B. Bundling, however, is not a profitable strategy unless the strategy can deter the entry or induce the exit of the rival firm. In the terminology of Fudenberg and Tirole (1984), bundling is a "top dog" strategy, while non-bundling softens price competition and is a "puppy dog" strategy. (See Tirole 1988 for a discussion of the taxonomy of business strategies.)

Finally, note that given cost levels for each firm, non-bundling promotes *static* efficiency since it leads to production of B by the most efficient supplier. With bundling, however, production can come from the tying firm even though it has a higher cost of B as long as the cost disadvantage ($c_{B1} - c_{B2}$) is less than the surplus available in market A (s_A). In this simple model, the social and private incentives for (un)bundling coincide.

IV. Tying and the Incentive to Innovate

In this section, I extend the basic model of Section III by introducing the possibility of R&D, thereby endogenizing the final production cost of each firm. Specifically, I analyze a three-stage game identical to that above, except that firms engage in R&D competition before the pricing game. That is, in the first stage, the two firms decide whether or not to bundle. In the second stage, the two firms engage in cost reducing R&D activities. A price game ensues in the third and final stage, with the cost structure inherited from the realizations of R&D. As usual, I solve the game via backwards induction.

The analysis of the third stage is the same as above. To focus on the impact of

tying arrangements on R&D competition in the tied good market, I ignore the possibility of R&D in market A and focus on the incentives for R&D in market B.¹¹

Let m_1 and m_2 be the levels of cost-reducing R&D investments by firm 1 and firm 2, respectively. The R&D outcomes are stochastic and independent across firms: let x_1 and x_2 denote the cost realizations after R&D for firm 1 and firm 2. Then, x_1 is a random variable drawn from $[0, c_1]$ by a c.d.f. $F(\cdot|m_1)$ with positive density $f(\cdot|m_1)$ for all $m_1 > 0$. Similarly, x_2 is a random variable drawn from a c.d.f. $G(\cdot|m_2)$ with positive density $g(\cdot|m_2)$ with all $m_2 > 0$. Let $F_{m_1}(\cdot|m_1)$ and $F_{m_1 m_1}(\cdot|m_1)$ be the partial derivative and the second partial derivative of $F(\cdot|m_1)$ with respect to m_1 , respectively. $G_{m_2}(\cdot|m_2)$ and $G_{m_2 m_2}(\cdot|m_2)$ are defined analogously. I make the following assumptions.

Assumption 1. $F_{m_1}(\cdot|m_1) > 0$, $G_{m_2}(\cdot|m_2) > 0$, $F_{m_1 m_1}(\cdot|m_1) < 0$, and $G_{m_2 m_2}(\cdot|m_2) < 0$ for all $m_1, m_2, x_1 \in (0, c_1)$ and $x_2 \in (0, c_2)$.

Assumption 2. $F_{m_1}(x_1|0) = \infty$, $G_{m_2}(x_2|0) = \infty$, $F_{m_1}(x_1|\infty) = 0$, $G_{m_2}(x_2|\infty) = 0$, for all $x_1 \in (0, c_1)$ and $x_2 \in (0, c_2)$.

Assumption 1 means that raising investment in R&D reduces cost in the sense of (reverse) first-order stochastic dominance, and does so at a diminishing rate. Assumption 2 is a boundary condition that guarantees an interior Nash equilibrium in R&D investments.

1. No Bundling

In this case, consumers' purchase decisions for each product are independent of each other, which implies that each market can be analyzed separately.

Given firm 2's investment level m_2 , firm 1 chooses m_1 to maximize the following expression:

¹¹ In Choi (1996), in contrast, the leverage of monopoly power occurs as a result of creating an interdependence of R&D competition between the two product markets. Thus, the model in the present paper abstracts from this mechanism by assuming the R&D possibility in only one market.

$$\begin{aligned}
E[x_2 - x_1 | x_1 \leq x_2] - m_1 &= \int_0^2 \int_0^2 (x_2 - x_1) dF(x_1 | m_1) dG(x_2 | m_2) - m_1 \\
&= \int_0^2 \int_0^2 F(x_1 | m_1) dx_1 dG(x_2 | m_2) - m_1
\end{aligned} \tag{4}$$

where the last line follows by integration by parts. The first order condition for the optimal investment level of firm 1 is given by:

$$\int_0^2 \int_0^2 F_{m_1}(x_1 | m_1) dx_1 dG(x_2 | m_2) = 1 \tag{5}$$

Similarly, firm 2's optimal choice of m_2 given m_1 is derived as:

$$\int_0^1 \int_0^1 G_{m_2}(x_2 | m_2) dx_2 dF(x_1 | m_1) = 1 \tag{6}$$

Equations (5) and (6) implicitly define firm 1's and 2's reaction functions, respectively, $m_i = R_i(m_j)$, where $i=1,2$ and $i \neq j$. The total differentiation of the first-order conditions yields the result that $R_i' < 0$. Let m_1^* and m_2^* be the Nash equilibrium R&D investment levels under nonbundling. Then, (m_1^*, m_2^*) can be derived by at the intersection of the two reaction functions. I further assume that $|R_i'| < 1$. This ensures the uniqueness and the stability of the Nash equilibrium.

2. Bundling

Without bundling, firm 1 sells product B only in the event of $S = \{(x_1, x_2) \in [0, c_1] \times [0, c_2] | x_1 \leq x_2\}$. In other words, any marginal cost reduction from investing in R&D is useful only when the event S occurs. With bundling, firm 1 behaves as if its cost of product B were $(x_1 - s_A)$, where $s_A = v_A - c_A (>0)$. Thus, firm 1 sells the bundled product in the event of $\tilde{S} = \{(x_1, x_2) \in [0, c_1] \times [0, c_2] | x_1 \leq x_2 + s_A\}$, which is larger than set S. In the event of set $\tilde{S}$, the tying firm's profit (gross of R&D investment cost) is given by $(x_2 + s_A - x_1)$. Thus, given firm 2's investment level m_2 , the tying firm's optimization problem is to maximize the following expression:

$$\begin{aligned}
E[x_2 + s_A - x_1 | x_1 \leq x_2 + s_A] - m_1 &= \int_0^1 \int_0^{c_2+s_A} (x_2 + s_A - x_1) dF(x_1 | m_1) dG(x_2 | m_2) - m_1 \\
&= \int_0^2 \int_0^{c_2+s_A} F(x_1 | m_1) dx_1 dG(x_2 | m_2) - m_1
\end{aligned} \tag{7}$$

where the last line once again follows by integration by parts. The first order condition for the optimal investment level of firm 1 is given by:

$$\begin{aligned} & \int_0^{\bar{x}_2} \int_0^{\bar{x}_1 + x_2} F_{m_1}(x_1 | m_1) dx_1 dG(x_2 | m_2) \\ &= \int_0^{\bar{x}_2} \int_0^{\bar{x}_1} F_{m_1}(x_1 | m_1) dx_1 dG(x_2 | m_2) + \int_0^{\bar{x}_2} \int_{\bar{x}_1}^{\bar{x}_1 + x_2} F_{m_1}(x_1 | m_1) dx_1 dG(x_2 | m_2) = 1 \end{aligned} \quad (8)$$

Equation (8) implicitly defines firm 1's reaction function under bundling, $\tilde{m}_1 = \tilde{R}_1(m_2)$. The comparison of (5) and (8) immediately gives the result that for any given level of m_2 , $\tilde{m}_1 = \tilde{R}_1(m_2) > m_1 = R_1(m_2)$: firm 1 has greater incentives for R&D after bundling. The reason for this result is that the marginal cost reduction through R&D translates into profits *conditional* on the firm being able to sell product B. With tying arrangements, the set of outcomes under which firm 1 sells is larger, ($\tilde{S}$ vs. S), and as a result firm 1's R&D incentives increase.

In contrast, firm 2's chances of selling product B decrease with firm 1's tying arrangements. Thus, firm 2's R&D incentives are reduced as a result of bundling. To verify this, note that the first order condition for firm 2's optimal investment level is given by:

$$\int_0^{\bar{x}_1} \int_0^{\bar{x}_1 - x_1} G_{m_2}(x_2 | m_2) dx_2 dF(x_1 | m_1) = 1 \quad (9)$$

Equation (9) defines firm 2's reaction function under bundling, $\tilde{m}_2 = \tilde{R}_2(m_1)$. The comparison of (6) and (9) gives the desired result, that is, for any given level of m_1 , $\tilde{m}_2 = \tilde{R}_2(m_1) < m_2 = R_2(m_1)$. Let $\tilde{m}_1^*$ and $\tilde{m}_2^*$ denote the Nash equilibrium R&D investment levels for the firm 1 (the tying firm) and firm 2 (the rival firm), respectively, under bundling. Then, $(\tilde{m}_1^*, \tilde{m}_2^*)$ can be derived by at the intersection of the two reaction functions $\tilde{R}_1$ and $\tilde{R}_2$.

Proposition 1. With bundling, the tying firm's R&D investment level increases ($\tilde{m}_1^* > m_1^*$), and the rival firm's R&D investment level decreases ($\tilde{m}_2^* < m_2^*$).

Sketch of the Proof. With bundling by firm 1, both firms' reaction curves shift. We can

consider the change in equilibrium as a result of sequential shifts of the two reaction curves. Let $(\hat{m}_1^*, \hat{m}_2^*)$ be the intersection point of $\tilde{R}_1(m_2)$ and $R_2(m_1)$. Since $\tilde{R}_1(m_2)$ is an outward shift of $R_1(m_2)$, we have $\hat{m}_1^* > m_1^*$ and $\hat{m}_2^* < m_2^*$ with the stability of Nash equilibrium.¹² $\tilde{R}_2(m_1)$ is an inward shift of $R_2(m_1)$, which implies that $\tilde{m}_1^* > \hat{m}_1^*$ and $\tilde{m}_2^* < \hat{m}_2^*$. Thus, we have $\tilde{m}_1^* > m_1^*$ and $\tilde{m}_2^* < m_2^*$. See Figure 1.

Proposition 1 tells us that the tying firm's R&D incentives increase at the expense of the rival firm's. The result is consistent with the empirical evidence in Vanderwerf (1990) who finds that most innovations in electronic wire preparation equipment have come from firms who also produced parts effectively tied to the equipment. It also renders some credibility to the argument that tying by a dominant firm can stifle innovation incentives by competitors in the tied good market.

In my model, market foreclosure does not necessarily lead to exclusion of the rival firm. Rather, market foreclosure in the product market translates into foreclosure in R&D markets. In the static model of price competition where the industry rent is *fixed*, bundling reduces the tying firm's overall profits since it intensifies the effective price competition in the tied good market. However, in the presence of dynamic rents that can be created through R&D, bundling may be a profitable strategy. The change in R&D incentives through bundling enables the tying firm to capture a larger share of dynamic rents. If this effect outweighs the negative effect of more aggressive price competition, bundling will be a privately optimal strategy even in the absence of exit by the rival firm.

This is an important point. One of the most startling aspects of the recent Microsoft case is that Robert Bork, a prominent member of the Chicago school who questioned the validity of the leverage theory, was retained by Netscape, asserting that Microsoft violated the law by using its dominant position in computer operating systems to promote its own browser over that of its rival. To the critics accusing him of "selling his soul",

¹² See Bulow *et al.* (1985) for the details of the proof.

Robert Bork responds by referring to the case of *Lorain Journal Company v. United States* in 1951. The Lorain Journal, a daily newspaper in Lorain, Ohio, had a virtual monopoly of the mass dissemination of news and advertising in the town. When there was a threat to the monopoly with the establishment of radio station WEOL in a nearby town, the newspaper refused to accept local advertising from any advertiser that used WEOL. The Lorain Journal's practice was deemed predatory by the Supreme Court, in violation of Section 2 of the Sherman Act. Bork (1998) argues that there is an exact parallel between the Lorain Journal case and the Microsoft case. Then, he reminds his critics that 20 years ago he wrote that the Lorain Journal case had been correctly decided. His critics, however, argue that the analogy is not exact because the Lorain case was concerned with the impending *extinction* of a radio broadcast station while Netscape is not facing such a fate. My model suggests that the exclusion of the rival firm is not necessary for tying arrangements to be privately optimal and/or to have potentially anti-competitive effects.

An important question is whether, in the presence of R&D competition, bundling is socially beneficial. In this model, the answer to this question rests on the nature of R&D competition. There are two aspects of R&D to consider in evaluating the efficiency of R&D competition. R&D competition promotes a *diversity* of research lines and thus increases the aggregate probability of success (the level of cost reduction) if the outcome of research project is uncertain. On the other hand, R&D competition can also result in the *duplication* of research efforts to the extent that their outcomes are correlated (Dasgupta and Maskin, 1987). The desirability of unfettered R&D competition hinges on the trade-off between diversity and duplication. To analyze this issue further, I consider a particular specification of the R&D process, the case with fixed intensities.

V. Welfare Analysis of Bundling with Fixed R&D Intensity

In this section, I consider the following specialization of the R&D process. Each

firm has the option of engaging in fixed intensity R&D activities, the cost of which is given by I . I assume the following specification of R&D technology. The outcome of R&D is modeled as a random draw of cost from a distribution. Let me further assume that the two firms are symmetric; they have the same initial cost of c ($c_{B1} = c_{B2} = c$) and have the access to the same technology.¹³ Specifically, if firm i invests in R&D at cost I , its cost will be given by a realization of the random variable x_i , drawn from $[0, c]$ with a c.d.f. $F(\cdot)$ and with positive density $f(\cdot)$. With this specification of R&D, let me analyze each firm's incentive to engage in R&D activities depending on whether or not firm 1 bundles. Note that by assuming the symmetry in the initial costs I abstract away from the issue of the *static* efficiency of bundling.

V.1 The Effects of Tying on R&D Incentives

1. No Bundling

Without bundling, I can analyze the R&D incentives in market B independently of the monopolized market. Therefore, the fact that firm 1 has monopoly power in the other market is irrelevant for the analysis of R&D competition in market B.

Let me denote the R&D decision of firm i by $I_i \in \{0, I\}$, $i = 1, 2$. Let $\pi_i(I_i, I_j)$ be the expected profit for firm i when its investment level is given by I_i and the other firm's investment level is given by I_j , where $i, j = 1, 2$, and $j \neq i$. Then,

$$\pi_i(I, I) = E[x_j - x_i \mid x_j > x_i] - I,$$

where x_i and x_j denote the post R&D costs for firm i and firm j , respectively, $j \neq i$.

Similarly,

$$\pi_i(I, 0) = E[c - x_i] - I,$$

$$\pi_i(0, I) = 0$$

Define $\mu_{11} = E[x_j - x_i \mid x_j > x_i]$ and $\mu_{10} = E[c - x_i]$. Then, $\mu_{10} > \mu_{11} > 0$.

It is immediate that we have the following Proposition for the equilibrium R&D behavior.

¹³ See the Appendix for an analysis of the asymmetric case.

Proposition 2. Without bundling, the equilibrium in R&D is characterized in the following way.

- (i) If $I \in L = [0, \mu_{11}]$, both firms invest in R&D.
- (ii) If $I \in M = (\mu_{11}, \mu_{10})$, there are two (asymmetric) pure strategy equilibria in which either only firm 1 or only firm 2 invests in R&D and there is one (symmetric) mixed strategy equilibrium in which both firms invest with probability $\frac{\mu_{10} - I}{\mu_{10} - \mu_{11}}$.
- (iii) If $I \in H = [\mu_{10}, \infty)$, neither firm invests in R&D.

2. Bundling

Let x_1 and x_2 be the post-R&D production cost in market B for firms 1 and 2 respectively. In the case of bundling, the tying firm behaves as if its production cost in market B is $x_1 - s_A$, where $s_A = v_A - c_A$. Thus, whether firm 1 will be able to sell the bundled product profitably depends on the relative magnitudes of $x_1 - s_A$ and x_2 . In order to reduce the number of cases to consider, let me assume that $s_A = v_A - c_A$ is sufficiently large that $x_1 - s_A$ is always less than x_2 .¹⁴ This implies that once the two products are bundled, the tying firm always finds it optimal to sell the bundled product irrespective of the R&D outcomes and forecloses the rival firm. It should be emphasized that the simplifying assumption is made purely for expositional simplicity and is not crucial for the analysis. Even if I consider the possibility that the tying firm cannot sell the bundled product profitably (i.e., $x_1 - s_A > x_2$), the main qualitative result will not change: the partial market foreclosure due to bundling reduces R&D incentives for the rival firm. However, with the assumption above, it is immediate that firm 2 has no incentive to invest in R&D since it knows that it will be completely foreclosed from market B. Given

¹⁴ A sufficient condition for this to hold is that $s_A = v_A - c_A > c_{B1}$. If this condition holds, the tying firm will still sell the bundled product even in the case where the rival firm reduces its production cost to zero and the tying firm maintains its initial production cost.

this fact, the tying firm will invest in R&D if and only if I is less than $\mu_{10} = E[c - x_i]$, which is the expected cost saving from R&D.

Proposition 3. With bundling, the tying firm will always foreclose the rival firm in the tied good market if the monopoly surplus from the tying good market ($s_A = v_A - c_A$) is sufficiently large. As a result the rival firm has no incentive to engage in R&D whereas the tying firm engages in R&D if its expected cost saving from R&D outweighs the cost of R&D investment ($I < \mu_{10}$).

Now let me consider the socially optimal configuration of R&D decisions to analyze the welfare implications of bundling. I define social welfare as the sum of industry profits and consumer surplus. The analysis is simple due to the assumption that consumers have a unit demand with the same reservation value. There is no price effect in welfare calculations since the price is just a transfer of money between firms and consumers; social welfare is maximized when the cost of providing the good is minimized.

I consider three possible configurations of R&D investment. If both firms invest in R&D, the expected total cost of product B is given by $E[\text{Min}(x_1, x_2)] + 2I$, where x_i is a random variable drawn from $[0, c]$ by a c.d.f. $F(\cdot)$ with positive density $f(\cdot)$. If only one firm invests in R&D, the expected total cost is $E[x_i] + I$. Finally, if nobody invests in R&D, the total cost is simply c . This leads me to the following Proposition (see also Figure 2).

Proposition 4. The socially optimal configuration of R&D investment is given by:

- (i) If $I \in L = [0, \mu_{11}]$, both firms should invest in R&D.
- (ii) If $I \in M = [\mu_{11}, \mu_{10}]$, only one firm should invest in R&D.
- (iii) If $I \in H = [\mu_{10}, \infty)$, neither firm should invest in R&D.

The comparison of Propositions 2, 3 and 4 reveals that bundling may or may not facilitate the convergence of privately and socially optimal R&D incentives.

If $I \in L$, the benefit of R&D diversification outweighs the cost of duplication. Thus, it is better to have both firms engage in R&D. In this case, nonbundling results in both firms investing in R&D, and the private and social incentives coincide. Bundling, however, eliminates firm 2's incentives to invest in R&D by foreclosing the market for firm 2. As a result, there is dynamic inefficiency associated bundling.

If $I \in M$, in contrast, the benefit of R&D diversification is outweighed by the cost of duplication. Thus, it is better to have only one firm engage in R&D. Bundling ensures that the private and social incentives coincide. Without bundling, whether private incentives result in socially optimal outcomes depends upon which of the multiple equilibria are selected. If one of the two asymmetric pure strategy equilibria is chosen, the private incentives again coincide with the socially optimal incentives. However, if the symmetric mixed strategy equilibrium is played, bundling improves dynamic efficiency. The reason is that with the symmetric mixed strategy equilibrium, the dynamic rents associated with R&D are completely dissipated with competition. Thus, in this case, bundling can serve as a welfare improving coordination mechanism.

V.2. The Incentives to Bundle

With the knowledge of how the R&D competition is played out under bundling and non-bundling, I can now analyze the incentives to bundle for firm 1. Note that I assumed that firm 1 does not have any initial cost disadvantage vis-à-vis firm 2 in market B. As a result, bundling has no (harmful) effect on the tying firm's profits without R&D considerations. Since bundling eliminates the incentives to invest in R&D for the rival firm, bundling will guarantee that the tying firm maintains a cost advantage in market B. Thus, there is no adverse effect of bundling from the price competition. The only effect from bundling is to reduce the R&D incentives of the rival firm. I can conclude that firm

1 always has the (weak) incentive to bundle if it has no initial cost disadvantage in product B.

Proposition 5. Firm 1 prefers to bundle if $I \in L \cup M$. If $I \in L$, bundling reduces welfare by eliminating the rival firm's R&D incentives. If $I \in M$, bundling can increase welfare by eliminating wasteful R&D competition if the symmetric mixed strategy is played under nonbundling. If $I \in H$, firm 1 is indifferent between bundling and nonbundling, and there are no welfare consequences of bundling.

A few remarks regarding the robustness of Proposition 5 are in order since it is based on special assumptions of the model. First, the result that bundling is always (weakly) preferred by firm 1 is not robust if I consider the case where firm 1 is initially less efficient than firm 2 in market B ($c_{B1} > c_{B2}$). In this case, there is the possibility that, ex post, the tying firm turns out to have a higher production cost even though it invested in R&D while the rival firm did not ($x_1 > c_{B2}$). Thus, the monopolistic supplier of A has to consider the negative consequences of price competition in its bundling decision. Firm 1 will bundle only when the beneficial effects of bundling in capturing the dynamic rents outweigh the negative effects of price competition. Intuitively, it is expected firm 1 will bundle if its initial cost disadvantage is not too large. In the Appendix, I analyze in detail the case of asymmetry in the initial costs when the realization of R&D outcome is uniformly distributed. I confirm the intuition by showing that bundling is beneficial if and only if $\gamma = \frac{c_{B1}}{c_{B2}} < 1 + \frac{2}{\sqrt{3}}$.

Second, the assumption of symmetry implies that the identity of the firm does not matter for welfare considerations when only one firm is engaged in R&D. However, if firms are not equal in their initial costs and/or in their R&D capabilities, we have to consider which firm should invest in R&D if only one firm is to do so. In other words, we have to be concerned with not only the aggregate level of R&D but also the

distribution of R&D investments across firms. This case is analyzed in detail in the Appendix.

Finally, I assumed a rectangular demand curve. If the demand curve is a more general downward-sloping one, the duplication in R&D success is not completely wasteful since there is a price effect that mitigates the cost of duplication. This price effect that results in a higher output should be also taken into account in the evaluation of bundling.

VI. Conclusion

The paper points out the possibility that bundling can tilt the playing field in favor of the tying firm in the R&D market. Tying arrangements prevent competitors from having a fair chance to reach consumers. This market foreclosure translates into reduced R&D incentives for the rival firms. Thus, it is possible that tying arrangements drive better products and services out of the market. However, it is also possible that tying arrangements enhance welfare by serving as a mechanism to coordinate and eliminate duplicative R&D activities. Presumably, this uncertainty concerning the welfare effects of tying suggests the difficulty of a simple legal standard to apply in antitrust cases. Nonetheless, the present paper formalizes the mechanism through which tying results in foreclosure in the innovation market. It also points out what are the crucial elements to consider in evaluating the welfare effects of tying. In particular, the nature of R&D competition that will take place without bundling should be an important criterion.¹⁵

¹⁵ In practice, other elements ignored in the simple model should be also considered. For instance, if the product is differentiated and/or if the demand curve is downward-sloping in the tied good market, the duplication of R&D activities would be less important. In this case, tying arrangements would have tendency to be more anti-competitive. However, as Microsoft argues, there may be also offsetting effects of tying such as enhanced performance due to a seamless integration of products if the tying good and the tied good are often used together.

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Appendix: The Analysis of Asymmetric Cost Structures

In the Appendix, I analyze the case where the two firms are asymmetric in their initial costs. Otherwise, I retain all the assumptions in Section V. Furthermore, I assume that the realization of R&D outcome is uniformly distributed; if a firm with a current unit cost of c performs R&D, the outcome of which will be a random variable $\tilde{c}$ distributed uniformly over $[0, c]$. When the two firms differ in their initial costs, this specification captures the following features of R&D process:

Diminishing Returns to R&D. When a firm with a current unit cost of c invests in R&D, the expected cost saving is given by $c/2$. As the original cost level c approaches to the limit zero, the expected cost saving or improvement from R&D decreases.

Experience Effects. However, the final expected cost (*Post* R&D cost) will be smaller for a firm with a lower initial production cost (*Pre* R&D cost).

The analysis in this Appendix runs parallel to the one in Section V, which can be considered as a special case of the analysis in the Appendix.

1. No Bundling

To analyze how the incentives for R&D depends on the initial cost structure, suppose that the initial costs of the two firms are given by c_L and c_H , where $c_L < c_H$. The firm with the initial cost of c_L (c_H) is called the low (high) cost firm. Let me denote the R&D decision of firm i by $I_i \in \{0, I\}$, $i = L, H$. Let $\pi_i(I_i, I_j)$ be the expected profit for firm i when its investment level is given by I_i and the other firm's investment level is given by I_j , where $i, j = L, H$, and $j \neq i$. Then,

$$\pi_H(I, I) = E[x-y \mid x > y] - I,$$

where x and y denote post R&D cost for the low cost firm and the high cost firm, respectively. By using the fact that x is uniformly distributed on $[0, c_L]$ and y is uniformly distributed on $[0, c_H]$,

$$\begin{aligned}\pi_H(I, I) &= E(x|x>y) - E[y|x>y] - I \\ &= \int_0^{c_L} \frac{x}{c_H} \frac{x}{c_L} dx - \int_0^{c_L} (1 - \frac{y}{c_L}) \frac{y}{c_H} dy - I \\ &= \frac{c_L^2}{6c_H} - I = \frac{c_L}{6\gamma} - I, \text{ where } \gamma = \frac{c_H}{c_L} \geq 1.\end{aligned}$$

By proceeding in a similar manner, I have

$$\pi_H(I, 0) = \frac{c_L^2}{2c_H} - I = \frac{c_L}{2\gamma} - I$$

$$\pi_H(0, 0) = \pi_H(0, I) = 0$$

$$\pi_L(I, I) = \frac{3c_H^2 - 3c_Hc_L + c_L^2}{6c_H} - I = \frac{c_L}{6\gamma} + \frac{(\gamma-1)c_L}{2} - I$$

$$\pi_L(I, 0) = c_H - \frac{c_L}{2} - I = (\gamma - \frac{1}{2})c_L - I$$

$$\pi_L(0, 0) = c_H - c_L = (\gamma - 1)c_L$$

$$\pi_L(0, I) = \frac{(c_H - c_L)^2}{2c_H} = \frac{(\gamma - 1)^2 c_L}{2\gamma}$$

Thus, I can draw the following payoff matrix as in Figure A-1.

		The High Cost Firm (H)	
		R&D Investment	No Investment
The Low Cost Firm (L)	R&D Investment	$\frac{c_L}{6\gamma} + \frac{(\gamma-1)c_L}{2} - I, \frac{c_L}{6\gamma} - I$	$(\gamma - \frac{1}{2})c_L - I, 0$
	No Investment	$\frac{(\gamma-1)^2 c_L}{2\gamma}, \frac{c_L}{2\gamma} - I$	$(\gamma - 1)c_L, 0$

Figure A-1. The Payoff Matrix of the R&D Game with Non-bundling

A straightforward calculation yields the following result.

Proposition 2A. Without bundling, the equilibrium in R&D is characterized in the following way.

The large Efficiency Gap Case ($\gamma = c_H / c_L > 5/3$)

In this case, the equilibrium is unique and is characterized in the following way.

- (i) If $I \in L = [0, \frac{c_L}{6\gamma}]$, both firms invest in R&D.
- (ii) If $I \in M = [\frac{c_L}{6\gamma}, \frac{c_L}{2}]$, only the low cost firm invests in R&D.
- (iii) If $I \in H = [\frac{c_L}{6\gamma}, \infty)$, neither firm invests in R&D.

The Small Efficiency Gap Case ($\gamma = c_H / c_L < 5/3$)

In this case, the same behavior as in the large gap case constitutes an equilibrium behavior. But the equilibrium is not unique for the intermediate values of I . More specifically, in this case there exists a set $m = [\frac{(3\gamma - 2)c_L}{6\gamma}, \frac{c_L}{2\gamma}]$ which is contained in M ($m \subset M$). If $I \in m$, there are two additional equilibria, one in pure strategies where only the high cost firm invests and another in mixed strategies where the low cost firm invests with probability $\frac{3(c_L - 2\gamma I)}{2c_L}$ and the high cost firm invests with probability $\frac{3\gamma(c_L - 2I)}{2c_L}$.

2. Bundling

Once again, let me make the assumption that $s_A = v_A - c_A$ is sufficiently large that $x_1 - s_A$ is always less than x_2 . Then, firm 2 has no incentive to invest in R&D since it knows that it will be completely foreclosed from market B. Given this fact, the tying firm will invest in R&D if and only if I is less than $c_{B1} / 2$, which is the expected cost saving from R&D.

Proposition 3A. With bundling, the rival firm has no incentive to engage in R&D whereas the tying firm engages in R&D if its expected cost saving from R&D outweighs the cost of R&D investment ($I < c_{B1}/2$).

For the analysis of the first-best socially optimal configuration of R&D decisions, I first note that if only one firm is to invest in R&D, it should be the low cost firm for efficiency. This follows from the assumption of *experience effects* in the R&D process. Thus, we can consider three possible configurations of R&D investment. If both firms invest in R&D, the expected total cost of product B is given by $E[\text{Min}(x, y)] + 2I$, where x is uniformly distributed on $[0, c_L]$ and y is uniformly distributed on $[0, c_H]$. If only the low cost firm invests in R&D, the expected total cost is $E[x] + I$. Finally, if nobody invests in R&D, the total cost is simply c_L . This leads me to the following Proposition.

Proposition 4A. The socially optimal configuration of R&D investment is given by:

- (i) If $I \in L = [0, \frac{c_L}{6\gamma}]$, both firms should invest in R&D.
- (ii) If $I \in M = [\frac{c_L}{6\gamma}, \frac{c_L}{2}]$, only the low cost firm should invest in R&D.
- (iii) If $I \in H = [\frac{c_L}{2}, \infty)$, neither firm should invest in R&D.

The comparison of Propositions 2A, 3A and 4A reveals that the private R&D incentives are more closely aligned with the socially optimal incentives under bundling when the cost asymmetry is taken into account. The social incentives and private incentives coincide without bundling in the case of large efficiency gap, and also in the small efficiency gap case to the extent that the equilibrium with the low cost firm investing is chosen in the case of multiple equilibria parameter region. Thus, bundling will distort efficiency in R&D decision if it changes the incentives.

With the knowledge in hand of how the R&D competition and the price competition play out under bundling and non-bundling, I can now analyze the incentive to bundle for firm 1. I consider two cases depending on whether or not the monopolistic supplier of product A is also initially more efficient supplier of product B.

1. Firm 1 is initially more efficient than firm 2 in market B ($c_{B1} < c_{B2}$)

In this case, it has been shown that bundling has no (harmful) effect on the tying firm's profits without R&D considerations. Since bundling eliminates the incentives to invest in R&D for the rival firm, bundling will guarantee that the tying firm maintains a cost advantage in market B. Thus, there is no adverse effect of bundling from the price competition. The only effect from bundling is to reduce the R&D incentives of the rival firm. I can conclude that firm 1 always has the incentive to bundle if it has an initial cost advantage in product B.

2. Firm 1 is initially less efficient than firm 2 in market B ($c_{B1} > c_{B2}$)

In this case, it is still possible that the tying firm turns out to have a higher production cost even after it invests in R&D while the rival firm did not. Thus, the monopolistic supplier of A has to consider the negative consequences of price competition in its bundling decision. Only when the beneficial effects of bundling in capturing dynamic rents outweighs the negative effects of price competition, it will bundle. Moreover, the portion of R&D benefits in cost reduction used to catch up with the rival firm's cost, which is $(\gamma-1)$ does not contribute to the net profit. Thus, firm 1 will choose to bundle only when its initial cost disadvantage is not sufficiently large. A straightforward calculation of firm 1's profits under bundling and nonbundling yields the result that firm 1 chooses to bundle if and only if $\gamma = \frac{c_{H1}}{c_{H2}} < 1 + \frac{\sqrt{2}}{\sqrt{3}}$.

Proposition 5A. If $I \in L \cup M$ and $\frac{c_{B1}}{c_{B2}} < 1 + \sqrt{\frac{2}{3}}$, firm 1 (weakly) prefers to bundle. If $I \in$

L , bundling unambiguously reduces welfare by eliminating the R&D incentives of the rival firm. If $I \in M$, there are two cases to consider.

Case 1. $c_{B1} < c_{B2}$

If $\gamma = \frac{c_{B2}}{c_{B1}} < 5/3$, bundling can increase welfare by serving as a coordinating

mechanism in the R&D game.

Case 2. $c_{B1} > c_{B2}$

If $5/3 < \gamma = \frac{c_{B1}}{c_{B2}} < 1 + \sqrt{\frac{2}{3}}$, bundling reduces welfare by inducing the less efficient

firm to invest in R&D at the expense of R&D investment by the more efficient firm.

If $\gamma = \frac{c_{B1}}{c_{B2}} < 5/3$, the welfare consequences of bundling depends on the selection of

equilibrium under nonbundling. If the equilibrium is the one in which only the more efficient rival firm invests in R&D, bundling reduces welfare. However, the mixed strategy equilibrium is played, bundling partially solves a coordination failure problem and improves welfare.

Figure 1. Equilibrium in R&D Investment under Bundling and Nonbundling

Figure 2. Market Equilibrium vs. Socially Optimal Outcome

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