The Browser Wars: Tying, Market Competition, and Welfare Implications for the Microsoft Antitrust Cases

by

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Abstract

This paper investigates the economic effects of tying and other business strategies (e.g., process innovations or R&D investments) on consumer benefit and social welfare, focusing particularly on the landmark Microsoft antitrust cases. We develop a model that captures the idiosyncratic characteristics of the operating system monopoly (i.e., Windows dominance) and of the oligopolistic market for browsers (e.g., Internet Explorer and Netscape's Navigator). We first examine the case of tying behavior in which Microsoft integrates IE into Windows to generate a bundled system good for sales, as compared to the no-tying case when Microsoft is required by the government to break into smaller entities. Given the asymmetric vertical market structure with an essential product component, we show that Microsoft's tying enhances price competition and the integration of IE with Windows is a socially desirable system good. We find that a Microsoft breakup stifles competition, hurts consumers, and is socially undesirable. We then examine the case where Microsoft and Netscape compete in undertaking process innovations or R&D activities in order to improve their respective positions in the browser market. We show that tying *cum* R&D as a business strategy makes all firms and consumers better off when the intensity of market competition (or the degree of product substitutability) is below a sufficiently low threshold level. But when the intensity of market competition exceeds the low threshold level, Microsoft is able to eliminate Netscape from the browser market without negatively affecting consumer surplus and social welfare. The welfare analysis of this paper has implications for the Microsoft cases and for antitrust policies in the New Economy markets.

Keywords: browser wars; tying; Microsoft antitrust cases; consumer benefits; overall welfare
JEL codes: L51, L12; L43

1. Introduction

In 2004, the European Commission (EC) decided that Microsoft unlawfully tied the sales of Windows Media Player (WMP) to its dominant Windows' operating systems. On January 14, 2008, the EC announced that Opera, the Norwegian web-browser developer, had filed a complaint against Microsoft's illegal tying of Internet Explorer (IE) to its Windows. On January 19, 2009, the EC sent a Statement of Objectives to Microsoft, alleging that "Microsoft's tying of Internet Explorer to the Windows operating system harms competition between web browsers, undermines product innovation and ultimately reduces consumer choice." This marked what the critics called *Browser War 2.0,* which was a newer version of *Browser War 1.0* between Netscape's Navigator and Internet Explorer before the millennium. In 2000, the U.S. Department of Justice called for the Microsoft's breakup for reasons that included the following: (1) it monopolized the market for the operating systems; (2) its integration of IE into Windows was anti-competitive; (3) its free distribution of IE was predatory; (4) it engaged in anti-competitive contracts with personal computer manufactures and internet service providers; (5) it impeded product innovation; and (6) its competitive actions harmed consumers.[1] But the U.S. government's antitrust litigation against Microsoft was eventually overturned. In the European Microsoft case, the EC argued that Microsoft had abused market dominance in its operating systems by tying the sales of WMP to Windows. Unlike the U.S. Microsoft case, the EC was successful in ruling against Microsoft and the company was required to offer a version of Windows without its WMP or IE. [2] One puzzling question is: From the antitrust perspectives of promoting competition and enhancing consumer benefits, is the newer version of *Browser War* better than the old one?

This paper contributes to the academic literature on the Microsoft cases by presenting an economic theory of the browser wars, hoping to shed some light on issues of antitrust policies toward tying and other business strategies (e.g., process innovations or R&D) in the New

[1] For academic debate and analysis of the U.S. Microsoft case a little more than a decade ago, see, for example, Benjamin (2001), Economides (2001), Fisher and Rubinfeld (2000), Fisher (2001), O'Brien (2001), Gilbert and Katz (2001), and Whinston (2001). For recent studies on the U.S. and E.U. Microsoft cases, see, for example, Economides (2007) and Economides and Lianos (2010).

[2] Microsoft was also required to offer to potential competitors "complete and accurate specifications for the protocols used by Windows work group servers in order to provide file, print, and group and user administration services to Windows work group networks." See Case COMP/C-3/37.792 Microsoft, Commission Decision of 24 March 2006. The document is available at: http://www.microsoft.com/presspass/download/legal/europeancommission/03-24-06EUDecision.pdf.

Economy markets. In our analysis of tying behavior that involves a key product component (Windows' operating system) indispensable to system goods for final consumption,[3] we show that Microsoft's tying is a pro-competitive business strategy which benefits consumers and the society as a whole.[4] At the outset, we note that the main issue is not Microsoft's Windows monopoly *per se* since barriers to entry in the market for the operating systems are fundamentally technological in nature and are prohibitively high. The main issue of concern is barriers to entry in the internet browser market. These entry barriers are due to the fact that software applications are written to run on the operating systems such as Microsoft's Windows and the great many of these applications make Windows appealing to computer users. Does tying allow Microsoft to extend its monopoly position in Windows' operating systems to the browser market at the expense of consumers? Will the Microsoft's strategic actions reduce competition and hamper product innovation at the expense of the society? To answer these important questions, we set up a model that takes into account the idiosyncratic characteristics of Windows monopoly and of the oligopolistic browser market (e.g., Internet Explorer and Netscape's Navigator). First, consumers have the option of buying Windows and IE integrated as a bundled system good, or buying a version of Windows without IE. Second, consumers can combine Windows with Netscape's Navigator as their own system good. Third, only the system goods generate consumer utility, not any of the product components individually. As such, competition between IE and Navigator is carried out through competing market demands for the system goods. These features distinguish our system-good model from the traditional leverage analyses of multiple-product firms and tying in the industrial organization literature.

In Browser War 1.0, Microsoft was once ordered by the U.S. government to restructure its operations into two identities: one to license and promote Windows' operating systems for personal computers, and the other to focus only on its application software business. In view of this observation, we discuss two scenarios: one involves the tying of IE with Windows while the other involves the sales of these two product components under separate entities. We present a welfare comparison between the alternative scenarios of tying and a breakup. We further

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[3] A system good is composed of two strictly complementary components. The components generate no consumer utility in isolation. We borrow this idea from the contributions by Katz and Shapiro (1994) and Farrell and Katz (2000).

[4] As the focus is on the economics of tying and other business strategies and their welfare implications for social welfare, this paper makes no attempt to offer a historical review of court battles between governments and defendant Microsoft Corporation.

investigate tying and R&D investments when Microsoft and Netscape compete for their respective positions in the browser market. The questions we wish to answer are: Would Microsoft's tying tactics lower its incentive to invest in R&D? If not, would tying and R&D competition allow Microsoft to eliminate Netscape from the browser market? What are possible effects on consumer benefits and social welfare?

We summarize the main findings of the paper in three parts. (1) Given the asymmetric vertical market structure with a product component indispensable to a system good, Microsoft's tying enhances price competition in the browser market. This increased competition leads the prices of IE and Navigator to go down, allowing Microsoft to increase the sales of Windows due to its indispensability. The interaction of the two firms is as follows. Tying allows Microsoft to charge a higher price for Windows, as compared to the case of no-tying. As such, Microsoft is able to use the monopoly rents to internally subsidize its IE, which is integrated with Windows as a system good. Microsoft sells the system good as a package deal in one price, without charging a separate price for IE. However, IE has a positive "shadow price," which is lower than the price set by Netscape for its Navigator. Their price difference reflects a bundled discount to consumers who purchase the integrated system good from Microsoft. As a result, Microsoft's system good is less expensive than the system good that combines Windows with Navigator. Despite price discrepancy between the two system goods, both goods are demanded due to the nature of product differentiation to consumers. Netscape makes positive profits so that there is no foreclosure or exclusion problem. Given that Windows is indispensable to either system good and that there is a bundled discount, Microsoft makes more profits and has a higher share of the browser market than Netscape's. (2) If tying is made unlawful, Microsoft is required to break up its business into separate entities. This breakup is shown to reduce competition in the browser market. The entity selling Windows lowers the product's price in order to increase its sales. However, the other entity selling IE charges a higher price than its shadow price when integrated with Windows as a system good. There is no such thing as internal subsidization after the breakup and the separate entities make completely opposite pricing decisions. As a consequence, Netscape follows suit and raises its price for Navigator. In equilibrium, market prices for the two system goods are identical, regardless of product differentiation between IE and Navigator. Netscape is able to increase its market share and make higher profits when tying is prohibited. The equilibrium prices for the system goods are relatively higher when Microsoft is broken up than when it is able to tie. A Microsoft breakup is thus socially undesirable as it reduces consumer benefits and overall welfare. (3) In the present of tying, R&D competition between the two firms to increase the sales of their browsers triggers Microsoft to adopt an aggressive price-discrimination strategy. Microsoft charges a relatively higher price for Windows than for its integrated system good. This strategy is anti-competitive as it "punishes" consumers who purchase Netscape for their personal computers but not IE. Consequently, foreclosure of Netscape is highly likely even when the intensity of market competition is low. This suggests that tying *cum* R&D competition may result in the total exclusion of Netscape from the browser market. Nevertheless, the relatively lower price of Microsoft's integrated system good, resulting from R&D competition, benefits consumers and the society as a whole.

In the case of *U.S. v. Microsoft*, the government accused Microsoft of the free distribution of its IE and the tying of IE with Windows as a predatory strategy and an anti-competitive action. One argument against Microsoft's conduct cited the Department of Justice as it successfully forced American Telephone and Telegraph (AT&T) to break up into several "Baby Bells" in 1980s. This argument goes like this: by dividing Microsoft into two or three entities ("Baby Bills") would force the company to compete on equal footing with Netscape. Because of increased competition, computer users would be better off. Our model suggests that a Microsoft breakup does not increase competition in the browser market. If Microsoft were broken up, the firm would charge a lower price for Windows in order to increase revenues from its sales.[5] The decrease in the price for Windows is not the overwhelming reason to support the government's antitrust intervention, however. The cheaper Windows itself does not generate utility to consumers unless they also purchase IE or Navigator. Our model predicts that the prices of IE and Navigator would go up, causing the equilibrium prices for system goods to increase. Consumers would not benefit from a Microsoft breakup.

In Browser War 2.0, the European Commission's successful antitrust intervention against Microsoft forced the company to supply a clean version of Windows without the WMP, among other remedies. According to our model results, this intervention undoubtedly benefits the E.U. suppliers of software applications. However, one wonders whether the EC failed to recognize that Microsoft with its market power on Windows operating systems may benefit consumers by

[5] Given that a monopoly produces and sells its product at which market demand is elastic, its total revenue increases when the product price decreases.

integrating its software applications to Windows. It should be noted that not all tying strategies are created equal in terms of their economic effects on consumer benefits and social welfare (Klein and Saft, 1985; Tirole, 2005). It depends crucially on (i) whether there is a core component technologically indispensable to any of the bundled products which constitute as system goods for final consumption, and (ii) whether each product component in a bundled package can be individually consumed or not. The traditional leverage theory of tying considers the case that each product in a bundle is consumable in isolation. The theory predicts that tying as a profitable strategy allows a multi-product firm to leverage and extend market power from its monopoly product to a related product. Consequently, tying *may* be welfare-deteriorating as the multi-product firm abuses the monopoly power to the detriment of consumers. The leverage analysis was articulated by the European Commission to win the E.U. antitrust case against Microsoft (Economides, 2007; Economides and Lianos, 2010). The leverage theory offers important insight into the effects of tying.[6] But the applicability of the theory to evaluate and support the E.U. Microsoft antitrust case may pose a problem when there are system goods.

The structure of the remainder is organized as follows. In Section 2, we develop an analytical framework for Browser War 1.0 in which a dominant firm integrates its application software with the operating system, while competing with an independent application software supplier. We consider the possibility that consumers combine the operating system with the alternative application software. We then analyze the case when the dominant firm is broken up into smaller entities. In Section 3, we conduct a welfare comparison between the alternative cases of tying and a breakup. In Section 4, we focus on tying behavior with strategic R&D competition and examine their effects on market equilibrium. We further show the possibility of foreclosure. In Section 5, we examine the case of Brower 2.0 and discuss its welfare implications. Concluding remarks can be found in Section 6.

2. The Analytical Framework of Browser War 1.0

Browser War 1.0 involves competition between domestic producers in the internet browser market. In this section, we lay out a system-good model for characterizing the equilibrium

[6] For contributions in the tying literature see, e.g., Adams and Yellen (1976), McAfee, McMillan, and Whinston (1989), Whinston (1990), Carlton and Waldman (2002), Choi (2004), and McAfee, McMillan, and Nalebuff (2004).

outcome when a dominant firm is permitted to tie its product components. We then analyze the case when the tying firm is required by the antitrust law to divide its operations into smaller entities.

2.1 Tying

We first examine the case of tying behavior. Consider a dominant firm, M, that produces an operating software O and an application software (denoted as 1).[7] Firm M is the only significant supplier of the operating software in the computer industry.[8] There is independent firm, N, selling a heterogeneous application software (denoted as 2). Each of the application software components is not attractive to consumers unless it is combined with the operating software to form a system good for final consumption. We assume that application software 2 and the operating software are compatible. We thus have an asymmetric vertical structure with the operating software monopoly and the oligopolistic market for the application software products.

Consumers have the option of buying the operating software O and application software 1 from firm M as a factory-integrated system good. Denote S_M as the price that firm M charges for each pack of its system good. Consumers also have the option of combining the operating software O with application software 2 purchased from the independent vendor. This constitutes as a mixed-and-matched system good (Matutes and Régibeau, 1988). For analytical simplicity, one unit of the operating software is required for application software 2 in order for the mixed-and-matched system good to be effectively working.

Let P_O represent the price of the operating software that firm M charges when it is sold without the application. Further, let P_2 stand for the price of application software 2. The price of the mixed-and-matched system good is then given as

$$S_{O2} = P_O + P_2. \tag{1}$$

Only the system goods generate utility for consumers, not any of the product components individually. To characterize competition between the differentiated system goods, we assume

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[7] A more complete analysis should include hardware components of a personal computer. We focus on the sales of an operating system as it functions as a "brain" that manages computer hardware resources to optimize task performance. To avoid confusion with a system good, we use operating software to represent operating system.

[8] Geroski (2003, p.153) considers Windows as a *standard* in that "it has certain well-defined interfaces with complementary goods ("application programming interfaces", or APIs) which enable producers of complementary goods (applications software writers in this case) to produce products that work well with the standard."

that their market demands are specified as follows:[9]

$$D_M = \alpha - S_M + \gamma S_{O2} \text{ and } D_{O2} = \alpha - S_{O2} + \gamma S_M, \tag{2a}$$

where $\alpha > 0$ and $0 < \gamma < 1$. The value of γ reflects the degree of product substitutability (or the intensity of market competition) between the system goods to consumers. For γ close to zero, the two system goods become almost independent such that their market competition is very small. For γ close to 1, the two system goods become almost homogeneous or highly substitutable such that their market competition is severe. Substituting S_{O2} from equation (1) into equation (2a), we have market demands for the system goods as

$$D_M = \alpha - S_M + \gamma(P_O + P_2) \text{ and } D_{O2} = \alpha - (P_O + P_2) + \gamma S_M. \tag{2b}$$

Next, we determine consumer surplus from the system goods. Rewriting (2a) yields

$$S_M = \frac{1}{1-\gamma^2}[(1+\gamma)\alpha - D_M - \gamma D_{O2}] \text{ and } S_{O2} = \frac{1}{1-\gamma^2}[(1+\gamma)\alpha - D_{O2} - \gamma D_M]. \tag{2c}$$

Assuming that $\lambda \equiv \alpha/(1-\gamma)$, $b \equiv 1/(1-\gamma^2)$, and $e \equiv \gamma/(1-\gamma^2)$, we have from equations (2c) the inverse demands:

$$S_M = \lambda - bD_M - eD_{O2} \text{ and } S_{O2} = \lambda - bD_{O2} - eD_M. \tag{3}$$

Corresponding to these demands in (3), we have the following utility function:

$$U(D_M, D_{O2}) = \lambda(D_M + D_{O2}) - \frac{b(D_M^2 + D_{O2}^2)}{2} - eD_M D_{O2} + y, \tag{4}$$

where y is a numeraire good sold in a perfectly competitive market. This utility function allows us to derive consumer surplus, $CS \equiv U(D_M, D_{O2}) - S_M D_M - S_{O2} D_{O2}$. Making use of equations (3) and (4) and normalizing the value of y to zero, we calculate consumer surplus as

$$CS = \frac{1}{2}(bD_M^2 + bD_{O2}^2 + 2eD_M D_{O2}), \tag{5}$$

where the demand structure for the system goods, $\{D_M, D_{O2}\}$, is given in (2b).

We now proceed to analyze the pricing and production decisions of the two firms. We assume that both firms adopt a Bertrand strategy in maximizing their respective profits. Firm M

[9] The demand equations are similar to those of Dixit (1979) and Singh and Vives (1984), except that we allow for differentiated system goods. Because of the operating software monopoly and the oligopolistic markets for software applications, our model has an *asymmetric* vertical structure. This differs from Choi (2008), who examines mergers with bundling in complementary markets and competition between two systems in a *symmetric* vertical structure.

has two sources of profits: one from the sales of its integrated system good, and the other from that of the operating software O. The objective of firm M is to determine prices for its system good and the operating software, S_M and P_O, that maximize the variable profits as follows:[10]

$$\Pi_M = S_M D_M + P_O D_{O2} = S_M[\alpha - S_M + \gamma(P_O + P_2)] + P_O[\alpha - (P_O + P_2) + \gamma S_M]. \quad (6)$$

The first-order conditions for firm M are given, respectively, as

$$\frac{\partial \Pi_M}{\partial S_M} = \alpha - 2S_M + \gamma P_2 + 2\gamma P_O = 0, \quad (7a)$$

$$\frac{\partial \Pi_M}{\partial P_O} = \alpha + 2\gamma S_M - P_2 - 2P_O = 0. \quad (7b)$$

As for firm N, it sets price for its application software, P_2, that maximizes

$$\Pi_2 = P_2 D_{O2} = P_2[\alpha - (P_O + P_2) + \gamma S_M]. \quad (8)$$

The first-order condition for firm N is

$$\frac{\partial \Pi_2}{\partial P_2} = \alpha + \gamma S_M - 2P_2 - P_O = 0. \quad (9)$$

Solving equations (7a), (7b), and (9), we have

$$\tilde{S}_M = \frac{\alpha}{2(1-\gamma)}, \ \tilde{P}_O = \frac{\alpha(\gamma+2)}{6(1-\gamma)}, \text{ and } \tilde{P}_2 = \frac{\alpha}{3}, \quad (10a)$$

where $\tilde{S}_M$ is the equilibrium price of the factory-integrated system good, $\tilde{P}_O$ is that of the operating software, and $\tilde{P}_2$ is that the application software 2. From equation (10a), the equilibrium price of the mix-and-match system good is calculated to be

$$\tilde{S}_{O2} = \tilde{P}_O + \tilde{P}_2 = \frac{\alpha(4-\gamma)}{6(1-\gamma)}. \quad (10b)$$

It is easy to verify from equations (10a) and (10b) that

$$\tilde{S}_M < \tilde{S}_{O2},$$

which indicates that the factory-integrated system good is less expensive than the mixed-and-matched system good.

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[10] A software product's fixed overhead and development costs do not affect how it is priced because they are "sunk" before the product is available in the market. The marginal cost of producing an extra copy of the software product can be "very small," if not zero. Without lost of generality, we ignore fixed costs and assume zero marginal cost.

Given that it is a package deal, the dominant firm sells its system good at the price of $\tilde{S}_M$ without charging a separate price for application software 1. However, this application software has a positive "shadow price," denoted as $\tilde{P}_1$, which is strictly lower than the competitor's price, $\tilde{P}_2$. That is,

$$\tilde{P}_2 > \tilde{P}_1 = \tilde{S}_M - \tilde{P}_O = \frac{\alpha}{6} > 0. \quad (10c)$$

The difference between $\tilde{P}_2$ and $\tilde{P}_1$ reflects a price discount (ΔP) to consumers of the factory-integrated system good since

$$\Delta P = \tilde{S}_{O2} - \tilde{S}_M = (\tilde{P}_O + \tilde{P}_2) - \tilde{S}_M = \tilde{P}_2 - (\tilde{S}_M - \tilde{P}_O) = \tilde{P}_2 - \tilde{P}_1 > 0.$$

Despite the price discrepancy between the system goods, both of which are demanded. That is,

$$\tilde{D}_M = \frac{\alpha(\gamma+3)}{6} > 0 \text{ and } \tilde{D}_{O2} = \frac{\alpha}{3} > 0.$$

This is due to the nature of product differentiation to consumers.

With its monopoly over the operating software, the dominant firm's market share for its application software is:

$$\frac{\tilde{D}_M}{\tilde{D}_M + \tilde{D}_{O2}} = \frac{\gamma+3}{\gamma+5}.$$

Depending on the degree of product substitutability, γ, the dominant firm's share of the application software market ranges from 60% to 66.7%. The competitor's market share for its application software ranges from 33.3% to 40%.

Based on the equilibrium prices and quantities shown above, we calculate firm profits, consumer surplus, and social welfare:

$$\tilde{\Pi}_M = \frac{\alpha^2(5\gamma+13)}{36(1-\gamma)} > 0, \; \tilde{\Pi}_2 = \frac{\alpha^2}{9} > 0, \quad (10d)$$

$$\tilde{CS} = \frac{\alpha^2(5\gamma+13)}{72(1-\gamma)}, \tilde{W} = \tilde{CS} + \tilde{\Pi}_M + \tilde{\Pi}_2 = \frac{\alpha^2(7\gamma+47)}{72(1-\gamma)}. \quad (10e)$$

It is easy to verify the comparative statics concerning how the value of γ affects the equilibrium results. We summarize their implications in the following proposition:

PROPOSITION 1. *Despite tying by the dominant firm and its operating software monopoly, the independent application software firm is able to make positive profits. The greater the degree of product substitutability (i.e., the higher the degree of market competition) between the system goods, the low the price that the dominant charges for the integrated system good. In this case, the equilibrium quantity demanded of the integrated system good is larger, consumer surplus is greater, and social welfare is higher.*

The next issue of concern is whether the dominant firm's tying arrangement has a negative effect on consumer benefits or is socially welfare-deteriorating. To address this issue, we proceed to examine the scenario where the dominant firm is forced to divide into two entities.

2.2 The breakup of the dominant firm

Our aim in this section is to characterize the market equilibrium of the dominant firm's breakup, which results in two system goods mixed and matched by consumers. Assume that the dominant M is ordered by the government to separate its business two smaller entities. One entity, referred to as firm O, sells only the operating software O. The other entity, referred as firm R, sells only application software 1. The industry now has three independent firms, O, R, and N. Firm O continues to be the operating software monopoly, but firms R and N are two competitors in the market for the application software products.

Because of the breakup, there are two system goods completely mixed and matched by consumers. We denote S_{Oi} as the price of system good i that is composed of the operating software O and application software i, where $i = 1, 2$. Let the price of the operating software be denoted as P_O. Also, let the price of application software i be denoted as P_i. The price of each mixed-and-matched system good is:

$$S_{Oi} = P_O + P_i.$$

It is plausible to assume that the re-organization of the industry (say, due to antitrust intervention) does not exert any impact on consumer preferences over the system goods. That is, the degree of substitutability, γ, between the two mixed-and-matched system goods remains unchanged. Market demands for the two system goods assembled by consumers are then given as

$$Q_{O1} = \alpha - S_{O1} + \gamma S_{O2} \text{ and } Q_{02} = \alpha - S_{O2} + \gamma S_{O1}. \tag{11a}$$

That is,

$$Q_{O1} = \alpha - (P_O + P_1) + \gamma(P_O + P_2) \text{ and } \quad Q_{02} = \alpha - (P_O + P_2) + \gamma(P_O + P_1). \tag{11b}$$

In terms of λ, b, and e defined earlier, we rewrite equations (11a) and obtain the inverse demands:

$$S_{O1} = \lambda - bQ_{O1} - eQ_{O2} \text{ and } S_{O2} = \lambda - bQ_{O2} - eQ_{O1}. \tag{12}$$

Corresponding to the inverse demands in equation (12), we have the quadratic utility function:

$$U(Q_{O1}, Q_{O2}) = \lambda(Q_{O1} + Q_{O2}) - \frac{1}{2}b(Q_{O1}^2 + Q_{O2}^2) - eQ_{O1}Q_{O2} + y,$$

where y is a numeraire good sold in a perfectly competitive market. It is straightforward to show that consumer surplus, defined as $CS = U(Q_{O1}, Q_{O2}) - S_{O1}Q_{O1} - S_{O2}Q_{O2}$, is

$$CS = \frac{1}{2}(bQ_{O1}^2 + bQ_{O2}^2 + 2eQ_{O1}Q_{O2}), \tag{13}$$

where the demand structure for the system goods, $\{Q_{O1}, Q_{O2}\}$, is given in (11b).

Next, we determine the pricing and production decisions of the three independent firms. Firm O sets its price for the operating software that maximizes

$$\pi_O = P_O(Q_{O1} + Q_{O2}) = P_O[\alpha - (P_O + P_1) + \gamma(P_O + P_2) + \alpha - (P_O + P_2) + \gamma(P_O + P_1)]. \tag{14}$$

The FOC for firm O is:

$$\frac{\partial \pi_O}{\partial P_O} = 2\alpha - P_1 - P_2 - 4P_O + \gamma P_1 + \gamma P_2 + 4\gamma P_O = 0. \tag{15}$$

Firm R determines its price for application software 1 that maximizes

$$\pi_1 = P_1(Q_{O1}) = P_1[\alpha - (P_O + P_1) + \gamma(P_O + P_2)].$$

The FOC for firm R is:

$$\frac{\partial \pi_1}{\partial P_1} = \alpha - 2P_1 - P_O + \gamma P_2 + \gamma P_O = 0. \tag{16}$$

Firm N determines its prices for application software 2 that maximizes

$$\pi_2 = P_2(Q_{O2}) = P_2[\alpha - (P_O + P_2) + \gamma(P_O + P_1)].$$

The FOC for firm N is:

$$\frac{\partial \pi_2}{\partial P_2} = \alpha - 2P_2 - P_O + \gamma P_1 + \gamma P_O = 0. \tag{17}$$

Solving equations (15), (16), and (17) for the Bertrand-Nash equilibrium prices of the operating and application software products, we have

$$P_O^* = \frac{\alpha}{(1-\gamma)(3-\gamma)} \text{ and } P_1^* = P_2^* = \frac{\alpha}{3-\gamma}. \tag{18a}$$

The prices of the two mixed-and-matched system goods are:

$$S_{O1}^* = P_O^* + P_1^* = \frac{\alpha(2-\gamma)}{(1-\gamma)(3-\gamma)} \text{ and } S_{O2}^* = P_O^* + P_2^* = \frac{\alpha(2-\gamma)}{(1-\gamma)(3-\gamma)}. \tag{18b}$$

The equilibrium quantities of the two system goods are:

$$Q_{O1}^* = Q_{O2}^* = \frac{\alpha}{3-\gamma}. \tag{18c}$$

The firm that sells the operating software continues to enjoy its monopoly position. But regardless of the degree of substitutability between the two system goods, each application software firm has a market share of 50%.

We calculate the equilibrium profits of the three firms as

$$\pi_O^* = \frac{2\alpha^2}{(1-\gamma)(3-\gamma)^2} \text{ and } \pi_1^* = \pi_2^* = \frac{\alpha^2}{(3-\gamma)^2}. \tag{18d}$$

We further calculate the equilibrium values of consumer surplus and social welfare:

$$CS^* = \frac{\alpha^2}{(1-\gamma)(3-\gamma)^2} \text{ and } W^* = CS^* + \pi_O^* + \pi_1^* + \pi_2^* = \frac{\alpha^2(5-2\gamma)}{(1-\gamma)(3-\gamma)^2}. \tag{18e}$$

The next step of our analysis is to compare differences in the equilibrium outcomes between the dominant firm’s tying and its breakup.

3. Economic Implications of the Dominant Firm’s Breakup

In this section, we wish to examine the following questions. Would consumers benefit from the breakup of the dominant firm into two entities that sell the operating software and the application software separately? How would the dominant firm’s breakup affect the prices of the software products? What would be the effect on the application software competitor? Answers to these questions may have policy implications for tying arrangements and antitrust decisions on whether a dominant firm should be divided and the resulting effect on social welfare.

3.1 Effects of the breakup on consumers

To analyze how the interests of consumers are affected, we first look at the equilibrium prices of the software components before and after the dominant firm's breakup. A comparison between $\tilde{P}_O$ in equation (10a) and $\tilde{P}_O$ in equation (18a) reveals that

$$P_O^* < \tilde{P}_O.$$

Thus, the dominant firm's breakup lowers the price of the operating software. Nevertheless, the breakup reduces competition in the application software market. This can easily be verified from their price equations that

$$P_1^* > \tilde{P}_1 \text{ and } P_2^* > \tilde{P}_2.$$

The breakup of the dominant firm leads the application software entity to raises its product price. It is also in the best interest of the competitor to follow suit and raise its product price.

Interestingly, the entities of the dominant firm have completely different pricing strategies. The one selling the operating software O finds it is profitable to lower its price whereas the one selling application software 1 charges a relatively higher price.

As consumers derive their utility not from the software components individually but from the two system goods, we need to investigate how the breakup affects the equilibrium prices of the system goods. It follows from equations (10a), (10b), and (18b) that

$$S_{O1}^* > \tilde{S}_M \text{ and } S_{O2}^* > \tilde{S}_{O2}.$$

The breakup causes the price of each mixed-and-matched system good to go up, regardless of whether the operating software is used with application software 1 or 2.

The lower price of the operating software, P_O^*, resulting from the dominant's breakup, is insufficient to justify the appropriateness of the breakup, however. Quite to the contrary, the breakup reduces competition because the system goods become relatively more expensive.

A direct examination of consumer surplus between tying and a breakup (see equations (10d) and (18e)) reveals that

$$CS^* - \tilde{CS} = -\frac{\alpha^2(45+12\gamma-5\gamma^2)}{72(3-\gamma)^2} < 0.$$

This indicates that the dominant firm's breakup harms consumers. In other words, tying by the dominant firm makes consumers better off. We thus have

PROPOSITION 2. *Forcing the dominant firm to break up into two entities, with one selling the operating software and the other selling the application software separately, causes the price of the operating software to go down and that of the application software to go up. The higher price that the entity charges for its application software leads its competitor to increase product price for its application software. Consequently, the mixed-and-matched system goods become more expensive. The breakup of the dominant firm thus harms consumers.*

3.2 *Effects of the breakup on profits and market shares of the firms*

A comparison of firm profits in the alterative cases (see equations (10d) and (18d)) reveals that

$$(\pi_O^* + \pi_1^*) - \tilde{\Pi}_M = -\frac{\alpha^2(5\gamma+3)}{36(3-\gamma)} < 0.$$

After the breakup, the combined profits of the two entities without tying are lower than the profits of the dominant firm that ties.

Apparently, tying as a strategy is more profitable to the dominant firm than when it is broken up. This indicates that, relative to a breakup, tying allows the dominant firm to use the monopoly rents from the integrated system good segment to internally subsidize its application software segment. This internal subsidization leads the tying firm to charge a zero price for the application software despite the fact that it has a positive shadow price (see equation (10c)). Moreover, the internal subsidization leads the tying firm to charge a lower a lower price for its system good than the prices for the mixed-and-matched system goods as shown in Section 3.1. Consumers purchase more of the system goods when there is tying relative to the case when there is a breakup. These results reflect that tying is a mechanism to improve market efficiency (i.e., the ability to increase production and exhaust gains to consumers) when there are system goods.

As for the application software competitor, its profit is relatively higher when there is no tying arrangement of any form. That is,

$$\pi_2^* - \tilde{\Pi}_2 = \frac{\alpha^2\gamma(6-\gamma)}{9(3-\gamma)^2} > 0.$$

These results indicate conflicts of interest between the dominant firm and its competitor.

It is interesting to see how market shares of the firms in the application software market change before and after the breakup. Based on the findings in Section 2, we find that the independent firm's market share increases from somewhere between 33.3% and 40% when there is a tying to 50% when there is a breakup.

These findings can be used to explain why an application software supplier has a strong incentive to file petitions against tying arrangements by an operating software monopoly. Tying increases competition and hence hurts the competitor. We therefore have

PROPOSITION 3. *The dominant firm's breakup hurts the company itself but benefits its competitor in the application software market.*

3.3 Effects of the breakup on social welfare

What would be the effect of the dominant firm's breakup on overall welfare? We find that the effect is negative. That is, welfare is higher when firm M ties the application software with the operating software as an integrated system since

$$W^* - \tilde{W} = -\frac{\alpha^2(63 - 12\gamma - 7\gamma^2)}{72(3-\gamma)^2} < 0.$$

We thus have

PROPOSITION 4. *Forcing the dominant firm to break up into smaller entities generates a negative effect on social welfare.*

The implication of Proposition 4 is straightforward. The integration of the dominant firm's operating software and its application software is a socially desirable system good.

The U.S. government's antitrust case against Microsoft alleges that the company's free distribution of IE and the tying of IE with Windows are a predatory strategy and an anti-competitive action. Base on our model, we find that these allegations are not consistent with the economic principle of welfare maximization. We show that a Microsoft breakup into two smaller entities would lead the separate firms to raise the price of IE and lower the price of Windows. In equilibrium, its competitor would follow suit and raise the price for its application software. In other words, a Microsoft breakup would not intensify competition in the browser markets. On the contrary, it would reduce competition. Although the breakup of Microsoft would lead the company to price Windows at a lower level in order to increase its sales, the mix-and-match price of each system good to consumers would become more expensive. This is because, after the breakup, both application software products would be more expensive and consumers would end up paying a relatively higher price for each system good they assemble.

Having discussed the economic effects of tying on market competition, consumer benefits and social welfare, our next step is to analyze issues concerning the incentives of the firms to invest in R&D.

4. The Browser War that Involves Strategic Competition in R&D

Innovation for improving a firm's position in a competitive market includes various efforts to enhance the values of its products to consumers. There is no exception to the application software market. Innovation allows consumers to purchase software products at lower prices or enjoy improved versions of the products. Innovation is particularly important to the fast changing computer industry. In the application software market, for example, innovation is central to competition. By engaging in process innovations or strategic R&D to compete *for* the market, firms wish to develop "a 'killer' product, service, or feature that will confer market leadership and thus diminish or eliminate actual or potential rivals" (Evans and Schmalensee, 2002).

Will a dominant firm that ties its product components have an incentive to invest in R&D? Will the firm's integrated product design negatively affect R&D of its competitor? What are possible effects on the prices of system goods and software products, the benefits of consumers, as well as social welfare? In this section, we present an analysis to these questions. For simplicity, we consider process innovations that reduce cost (i.e., cost-reducing R&D activities).[11]

We analyze the scenario that the dominant firm invests in R&D for two obvious reasons. One is to develop an improved version of its application software. The other, which is most important of all, is to technologically integrate the application software with the operating software to produce a more attractive system good. The improvement of the integrated system good allows the dominant firm to increases its sales. Specifically, we consider a quadratic

[11] The analysis in this section is closely related to some studies in the literature on how tying and system goods would affect the incentives of firms to invest in R&D. See, for example, Farrell and Katz (2000) and Choi (2004). However, our model departs from these two studies in some important aspects. First, the two studies highlight the impact of R&D by firms on their product components. We consider the impact of R&D activities by the dominant firm on its integrated system good and the impact of R&D by the competitor on its application software. Second, the two studies use the Hotelling-type framework in their analyses. We introduce the notion of system goods into the traditional model of product differentiation and make use of the Marshallian demand structure in our analysis.

expenditure function for each firm's R&D investment (denoted as z_i for $i = 1, 2$). The dominant firm's R&D expenditure is taken to be $z_1^2/2$, which improves the efficiency of "wielding" its application software into the operating software to produce a more attractive a system good such that production cost decreases by an amount equal to $z_1 D_M$. The competitor's R&D expenditure is $z_2^2/2$, which improves the efficiency of producing its application software such that production cost decreases by an amount equal to $z_2 D_{O2}$. Stated alternatively, firms M and N are able to increase their revenues from sales by the amounts of $z_1 D_M$ and $z_2 D_{O2}$, respectively, due to their investments in R&D.

As in the R&D literature, we adopt a two-stage game. In the first stage, both firms independently and simultaneously determine their optimal levels of R&D investments. In the second stage, the firms adopt a Bertrand strategy in deciding on their prices that maximize individual profits.

We analyze the sub-game perfect equilibrium by backwards induction, starting with the second stage of the game. Given R&D investments, firm M determines the price of the factory-integrated system good, S_M, and that of the operating software, P_O, in order to maximize its joint profit:

$$\Pi_M = (S_M + z_1) D_M + P_O D_{O2} - \frac{z_1^2}{2}.$$

Substituting the demand structure from (2b) into the profit function, after rearranging terms, yields

$$\Pi_M = (S_M + z_1)[\alpha - S_M + \gamma(P_O + P_2)] + P_O[\alpha - (P_O + P_2) + \gamma S_M] - \frac{z_1^2}{2}.$$

The FOCs for firm M are:

$$\frac{\partial \Pi_M}{\partial S_M} = \alpha - 2S_M + \gamma P_2 + 2\gamma P_O - z_1 = 0, \tag{20}$$

$$\frac{\partial \Pi_M}{\partial P_O} = \alpha + 2S_M \gamma - P_2 - 2P_O + \gamma z_1 = 0. \tag{21}$$

Similarly, given R&D investments, firm N determines its price for application software 2, P_2, that maximizes

$$\Pi_2 = (P_2 + z_2)D_{O2} - \frac{z_2^2}{2} = (P_2 + z_2)[\alpha - (P_O + P_2) + \gamma S_M] - \frac{z_2^2}{2}.$$

The FOC for firm N is

$$\frac{\partial \Pi_2}{\partial P_2} = \alpha + S_M \gamma - 2P_2 - P_O - z_2 = 0. \tag{22}$$

Simultaneously solving the FOCs in (20), (21), and (22) yields

$$\tilde{S}_M = \frac{\alpha - (1-\gamma)z_1}{2(1-\gamma)},\ \tilde{P}_O = \frac{\alpha(2+\gamma) + \gamma(1-\gamma)z_1 + 2(1-\gamma)z_2}{6(1-\gamma)},\ \tilde{P}_2 = \frac{\alpha - \gamma z_1 - 2z_2}{3}, \tag{23a}$$

where $\tilde{S}_M$ is the equilibrium price of the factory-integrated system good, $\tilde{P}_O$ the equilibrium price of the operating software, and $\tilde{P}_2$ the equilibrium price of the independent firm's application software. The price of the mixed-and-matched system good is

$$\tilde{S}_{O2} = \tilde{P}_O + \tilde{P}_2 = \frac{\alpha(4-\gamma) - \gamma(1-\gamma)z_1 - 2(1-\gamma)z_2}{6(1-\gamma)}. \tag{23b}$$

Substituting the prices from (23a) and (23b) into the demand structure in (2b) yields the equilibrium quantities for the two system goods:

$$\tilde{D}_M = \frac{3\alpha + 3z_1 + \alpha\gamma - 2\gamma z_2 - \gamma^2 z_1}{6} \text{ and } \tilde{D}_{O2} = \frac{\alpha + z_2 - \gamma z_1}{3}. \tag{23c}$$

From equations (23), we have the following comparative-static results:

$$\frac{\partial \tilde{S}_M}{\partial z_1} < 0,\ \frac{\partial \tilde{S}_{O2}}{\partial z_1} < 0,\ \frac{\partial \tilde{P}_2}{\partial z_1} < 0,\ \frac{\partial \tilde{P}_O}{\partial z_1} > 0,\ \frac{\partial \tilde{P}_2}{\partial z_2} < 0,\ \frac{\partial \tilde{S}_{O2}}{\partial z_2} < 0,\ \frac{\partial \tilde{P}_O}{\partial z_2} > 0.$$

We summarize these results in the following proposition:

PROPOSITION 5: *Other things being equal, tying cum strategic R&D by the dominant firm lowers the prices of the two system goods and the price of the competitor's application software, but raises the price of its operating software. Strategic R&D by the competitor lowers the price of its own application software and that of the mixed-and-matched system good, but raises the price of the dominant firm's operating software.*

Proposition 5 has interesting implications. Strategic R&D competition benefits consumers as they pay a lower price for either system good. Consumers also benefit from a lower price for the application software sold by the independent firm. The only negative effect is on the price of the operating software.

We now proceed to analyze the first stage of the game in which the two firms determine their optimal levels of R&D investments. To do so, we calculate the profit functions of the two firms as follows:

$$\Pi_M = \frac{1}{36(1-\gamma)}\{13\alpha^2 - 9z_1^2 + 4z_2^2 - 5\gamma^2 z_1^2 + 5\gamma^3 z_1^2 + 18\alpha z_1 + 8\alpha z_2 + 5\alpha^2\gamma + 9\gamma z_1^2 - 4\gamma z_2^2 - 10\alpha\gamma^2 z_1 + 8\gamma^2 z_1 z_2 - 8\alpha\gamma z_1 - 8\alpha\gamma z_2 - 8\gamma z_1 z_2\}$$

and

$$\Pi_2 = \frac{2\alpha^2 - 7z_2^2 + 2\gamma^2 z_1^2 + 4\alpha z_2 - 4\alpha\gamma z_1 - 4\gamma z_1 z_2}{18}.$$

The dominant firm M chooses z_1 that satisfies its FOC:

$$\frac{\partial \Pi_M}{\partial z_1} = \frac{9\alpha - 9z_1 + 5\alpha\gamma - 4\gamma z_2 - 5\gamma^2 z_1}{18} = 0 \tag{24a}$$

and the independent firm N chooses z_2 that satisfies its FOC:

$$\frac{\partial \Pi_2}{\partial z_2} = \frac{2\alpha - 7z_2 - 2\gamma z_1}{9} = 0. \tag{24b}$$

Solving equations (24) for the optimal R&D investments by firms M and N yields

$$\hat{z}_1 = \frac{7\alpha + 3\alpha\gamma}{3\gamma^2 + 7} > 0 \text{ and } \hat{z}_2 = \frac{2\alpha(1-\gamma)}{3\gamma^2 + 7} > 0.$$

It comes as no surprise that the dominant firm undertakes a relatively higher level of R&D investment than its competitor since $\hat{z}_1 - \hat{z}_2 = [5\alpha(\gamma+1)]/(3\gamma^2+7) > 0$.

In the tying *cum* strategic R&D case, the price of the operating software, the equilibrium prices and quantities of application software and system goods are calculated as follows:

$$\hat{P}_O = \frac{\alpha(\gamma + \gamma^2 + 3)}{(1-\gamma)(3\gamma^2+7)},\ \hat{P}_2 = \frac{\alpha(1-\gamma)}{3\gamma^2+7},$$

$$\hat{S}_M = \frac{\alpha\gamma(3\gamma+2)}{(1-\gamma)(3\gamma^2+7)},\ \hat{S}_{O2} = \frac{\alpha(2\gamma^2 - \gamma + 4)}{(1-\gamma)(3\gamma^2+7)},\ \hat{D}_M = \frac{\alpha(2\gamma + \gamma^2 + 7)}{3\gamma^2+7},\ \hat{D}_{O2} = \frac{3\alpha(1-\gamma)}{3\gamma^2+7}.$$

We further calculate consumer surplus, firm profits, and social welfare:

$$\hat{\Pi}_M = \frac{\alpha^2(-\gamma^3 + 39\gamma^2 - 5\gamma + 67)}{2(1-\gamma)(3\gamma^2+7)^2},\ \hat{\Pi}_2 = \frac{7\alpha^2(1-\gamma)^2}{(3\gamma^2+7)^2},$$

$$\hat{CS} = \frac{\alpha^2(-5\gamma^3 + 3\gamma^2 - 6\gamma + 58)}{2(1-\gamma)(3\gamma^2+7)^2}, \ \hat{W} = \hat{CS} + \hat{\Pi}_M + \hat{\Pi}_2 = \frac{\alpha^2(-20\gamma^3 + 84\gamma^2 - 53\gamma + 139)}{2(1-\gamma)(3\gamma^2+7)^2}.$$

We proceed to compare the equilibrium outcomes between tying *cum* strategic R&D and tying without R&D.

4. 1 Effects of tying cum strategic R&D on prices and quantities

A comparison in equilibrium prices and quantities between the cases of tying *cum* strategic R&D and tying without R&D reveals the following:

$$\hat{P}_O - \tilde{P}_O = \frac{\alpha(3\gamma^2 + 3\gamma + 4)}{6(3\gamma^2+7)} > 0, \quad \hat{P}_2 - \tilde{P}_2 = -\frac{\alpha(3\gamma^2 + 3\gamma + 4)}{3(3\gamma^2+7)} < 0,$$

$$\hat{S}_M - \tilde{S}_M = -\frac{\alpha(3\gamma + 7)}{2(3\gamma^2+7)} < 0, \ \hat{S}_{O2} - \tilde{S}_{O2} = -\frac{\alpha(3\gamma^2 + 3\gamma + 4)}{6(3\gamma^2+7)} < 0,$$

$$\hat{D}_{O1} - \tilde{D}_{O1} = \frac{\alpha(-3\gamma^3 - 3\gamma^2 + 5\gamma + 21)}{6(3\gamma^2+7)} > 0,$$

$$\hat{D}_{O2} - \tilde{D}_{O2} = \frac{\alpha(-3\gamma^2 - 9\gamma + 2)}{3(3\gamma^2+7)} > (\leq)0 \text{ if } \gamma > (\leq)0.207.$$

Relative to tying without R&D, tying *cum* strategic R&D leads to the following results: (1) the dominant firm lowers the price for the integrated system good but raises the price for the operating system; (2) the independent firm lowers the price for its application software, and (3) the prices of the two system goods are lower. The quantity demanded of the factory-integrated system good unambiguously increases. But the quantity demanded of the mixed-and-matched system good may increase or decrease, depending on the degree of product substitutability.

Recall the analysis in Section 3.1 where we compare price changes for two cases: the dominant firm's tying without R&D and its breakup. We observe similar patterns of changes in product prices. But we find that tying *cum* strategic R&D further strengthens these price effects. To see this, we compare product prices for the three cases: trying *cum* strategic R&D, tying without R&D, and a breakup. We find that

$$\hat{S}_M < \tilde{S}_M < S_M^*, \ \hat{S}_{O2} < \tilde{S}_{O2} < S_{O2}^*, \ \hat{P}_2 < \tilde{P}_2 < P_2^*, \text{ and } \hat{P}_O > \tilde{P}_O > P_O^*.$$

The price of a given system good is at its lowest level in the tying *cum* strategic R&D case. This is also true for the price of the independent firm's application software. Nevertheless, the price of the operating software is at its highest in the tying *cum* strategic R&D case.

We find that tying *cum* strategic R&D widens the price discrepancy between the system goods, making the mixed-and-matched one relatively more expensive than the factory-integrated one. To see this, we note that

$$\tilde{S}_{O2} - \tilde{S}_M = \frac{\alpha}{6} > 0 \text{ and } \hat{S}_{O2} - \hat{S}_M = \frac{\alpha(\gamma+4)}{(3\gamma^2+7)} > 0$$

imply the following:

$$(\hat{S}_{O2} - \hat{S}_M) - (\tilde{S}_{O2} - \tilde{S}_M) = \frac{\alpha(-3\gamma^2 + 6\gamma + 17)}{6(3\gamma^2+7)} > 0.$$

Moreover, tying *cum* strategic R&D enables the dominant to adopt an aggressive pricing strategy as illustrated by the following:

$$\hat{S}_M - \hat{P}_O = -\frac{\alpha(3-2\gamma)(\gamma+1)}{(1-\gamma)(3\gamma^2+7)} < 0,$$

which implies that $\hat{S}_M < \hat{P}_O$. This result differs dramatically from the tying without R&D case (see equation (10c)) in which we show that $\tilde{S}_M > \tilde{P}_O$. Tying *cum* strategic R&D leads to an equilibrium outcome where the dominant firm sets a relatively higher price for the operating software than for the integrated system good. As a consequence, the mixed-and-matched system good consumers pay a higher price for the operating software. These consumers are "punished" by the dominant firm's price discrimination strategy. We thus have

PROPOSITION 6: *Tying cum strategic R&D competition widens the price discrepancy between the system goods. Moreover, the dominant firm charges a* <u>*higher*</u> *price for the operating software than for the factory-integrated system good. There is price discrimination against consumers who mix and match their own system good. This equilibrium outcome stands in contrast to the case of tying without R&D competition. In this later case, the dominant firm charges a* <u>*lower*</u> *price for the operating software than for the integrated system good.*

Proposition 6 has interesting implications for antitrust policy. In the presence of tying, competition in process innovations may be anti-competitive. Tying *cum* strategic R&D provides an opportunity for the dominant firm to adopt an aggressive strategy, which creates an anti-competitive effect on the pricing of the operating software. This leads us to see the resulting effects on the profits of the dominant firm and its competitor.

4.2 Effects of tying cum strategic R&D on firm profits: Foreclosure may emerge

The dominant firm finds tying *cum* strategic R&D to be a profitable strategy since

$$\hat{\Pi}_M - \tilde{\Pi}_M = \frac{\alpha^2(45\gamma^4 + 162\gamma^3 + 390\gamma^2 + 234\gamma + 569)}{36(3\gamma^2 + 7)^2} > 0.$$

However, engaging in R&D competition may or may not be a profitable strategy to the independent firm, depending on the degree of product substitutability.

There are two possibilities:

(i) $\hat{\Pi}_2 - \tilde{\Pi}_2 = -\frac{\alpha^2(9\gamma^4 - 21\gamma^2 + 126\gamma - 14)}{9(3\gamma^2 + 7)^2} > 0$ when $\gamma < 0.1133$;

(ii) $\hat{\Pi}_2 - \tilde{\Pi}_2 = -\frac{\alpha^2(9\gamma^4 - 21\gamma^2 + 126\gamma - 14)}{9(3\gamma^2 + 7)^2} < 0$ when $\gamma > 0.1133$.

When the value of γ is sufficiently low $(\gamma < 0.1133)$, strategic R&D is competition profitable to the independent firm since $\hat{\Pi}_2 > \tilde{\Pi}_2$. But when the value of γ is greater than 0.1133, strategic R&D competition becomes unprofitable since $\hat{\Pi}_2 < \tilde{\Pi}_2$.

These findings permit us to establish

PROPOSITION 7. *To the dominant firm, tying cum strategic R&D competition is unambiguously a more profitable strategy than tying without R&D. But the competitor may not find it profitable to engage in the R&D game unless the degree of product substitutability is sufficiently* <u>*low*</u>*. Moreover, tying cum R&D may exclude the competitor from the market, without requiring the degree of product substitutability (or the intensity of product market competition) to be high.*

The implications of Proposition 7 are straightforward. An independent firm may not afford to engage in an R&D game in competing with the dominant firm. In our analyses, tying without R&D does not result in foreclosing the competitor since it makes positive profits (see Proposition 1). Surprisingly, tying *cum* strategic R&D competition constitutes as a mechanism to exclude the competitor from the market.[12] It should be noted that this market exclusion arises from market competition in cost-reducing process innovations, not from anti-competitive actions

[12] Whinston (1990) shows that bundling as a mechanism enables a firm with monopoly power to leverage from its own market to foreclose the access of a rival in a second market. Church and Gandal (2000) consider the possibility of vertical foreclosure in system markets where a final good consists of hardware component and complementary software.

strategically designed to raise the costs of the competitor. These cost-raising actions may include withholding information updates for the operating software to the competitor or not fully releasing the application programming interface. Even without these anti-competitive, non-price actions, the total exclusion of the competitor is a possibility in an asymmetric vertical market structure with an essential product component (such as Windows).

It has been argued that Microsoft offers incentives to PC manufactures for installing the Windows operating systems and these manufactures find it more profitable to include Windows than a different operating system (such as Red Hat's Linux). Moreover, the manufactures are offered incentives to integrate Microsoft's Internet Explorer in Windows. The court argued that such distribution contracts were exclusive, restricting Netscape's ability to sell its browser. Our model results indicate that, without the exclusionary contracts, Microsoft's R&D activities have a "rent-shifting effect" to hurt Netscape, depending on the degree of substitutability between their competing products. That is, there are potential conflicts between process innovation and market competition (which leads to the exclusion of the competitor).

Our simple analysis suggests that antitrust intervention in innovative industries may be counter-productive. If antitrust policies are designed in part to ensure the viability of application software producers and to prevent the market from being monopolized by the dominant firm, setting limits on R&D competition appears to be an option.[13] Nevertheless, such an intervention over business innovations creates an antitrust dilemma. The R&D-deterring policy benefits independent software producers at the expense of consumers. We show this result in Section 4.3.

4.3 Effects of tying cum strategic R&D on consumer surplus and social welfare

The firms' R&D investments are shown to have a positive effect on consumers and the society as a whole since

$$\hat{CS} - \tilde{CS} = \frac{\alpha^2(45\gamma^4 + 162\gamma^3 + 552\gamma^2 + 990\gamma + 1451)}{72(3\gamma^2 + 7)^2} > 0$$

and

[13] Whinston and Segal (2007) develop a dynamic model of innovation to examine how antitrust intervention may affect profits of current incumbents and new entrants in innovative industries. New entrants undertake R&D to compete for the market and incumbents undertake R&D to improve their dominant market positions. The authors show, among other things, that a more protective antitrust policy benefits entrants at the expense of incumbents and that R&D-deterring activities may reduce tensions between the incumbents and the new entrants.

$$\hat{W} - \tilde{W} = \frac{\alpha^2(63\gamma^4 + 486\gamma^3 + 1500\gamma^2 + 450\gamma + 2701)}{72(3\gamma^2 + 7)^2} > 0.$$

Based on these findings, we have

PROPOSITION 8. *Tying cum strategic R&D competition has a positive effect on consumer benefits and social welfare.*

Propositions 7 and 8 imply that tying *cum* R&D as a competitive strategy makes all firms, consumers, and the society as whole better off when the degree of product substitutability is below a sufficiently low threshold level. When product substitutability exceeds the low threshold level, however, the dominant firm is able to eliminate its competitor from the market without having a negative effect on consumer surplus and social welfare.

5. Browser War 2.0: International Competition and Antitrust

Browser war 2.0 involves competition between browser producers across national boundaries. Methodologically speaking, the analytical framework of Browser 1.0 presented in the previous sections for the U.S. Microsoft antitrust case can also be applied to the E.U. Microsoft antitrust case. For the E.U. case that is concerned with international competition in the browser market, we now consider the dominant firm M as a *foreign* producer (i.e., Microsoft) and the independent firm N a *domestic* producer (e.g., Opera). In terms of modeling, we exclude the dominant firm's (that is, the foreign firm's) profits when we calculate the welfare function for the E.U. Social welfare for the E.U. (denoted as W^{EU}) is now specified as the sum of consumer surplus (CS) and the domestic producer's profits (Π_2). That is, $W^{EU} = CS + \Pi_2$.

Based on the analyses in Sections 3 and 4, we calculate the value of W^{EU} for the three different cases. We have $\tilde{W}^{EU}$ for the case of tying without R&D, $(W^{EU})^*$ for that of no-tying and no-R&D, and $\hat{W}^{EU}$ for that of tying *cum* R&D. We record their results as follows:

$$\tilde{W}^{EU} = \tilde{CS} + \tilde{\Pi}_2 = \frac{(7-\gamma)\alpha^2}{24(1-\gamma)},$$

$$(W^{EU})^* = CS^* + \Pi_2^* = \frac{(2-\gamma)\alpha^2}{(1-\gamma)(3-\gamma)^2},$$

$$\hat{W}^{EU} = \hat{CS} + \hat{\Pi}_2 = \frac{(-19\gamma^3 + 45\gamma^2 - 48\gamma + 72)\alpha^2}{2(1-\gamma)(3\gamma^2 + 7)^2}.$$

It is easy to verify that

$$\hat{W}^{EU} - \tilde{W}^{EU} = \frac{\alpha^2(-9\gamma^4 + 54\gamma^3 + 240\gamma^2 - 6\gamma + 521)}{24(3\gamma^2 + 7)^2} > 0$$

and

$$\tilde{W}^{EU} - (W^{EU})^* = \frac{(\gamma^2 - 12\gamma + 15)\alpha^2}{24(3-\gamma)^2} > 0.$$

The ranking of social welfare for the three cases is then given as follows:

$$\hat{W}^{EU} > \tilde{W}^{EU} > (W^{EU})^*.$$

We therefore have

PROPOSITION 9. *Consider an international antitrust case that involves competition between a foreign dominant firm and a domestic producer in the import-competing application software market. The importing country's social welfare in the case of tying cum strategic R&D is greater than that in the case of trying without R&D, which is greater than that in the case of no-tying and no-R&D. From the welfare perspective, tying is preferred to no-tying.*

The findings of Proposition 9 imply that, other things being equal, the successful E.U. antitrust litigation against Microsoft makes the EC applications software suppliers better off at the expense of consumers and the European Community as a whole.

The EC's accusation of Microsoft for tying and other business conduct leads the company to pay billion dollars of fines. These fines can fundamentally be interpreted as "tariffs" imposed on an exporter by the importing country within the context of international competition or trade protectionism. Our simple welfare analysis ignores these fines, which constitute a sizable amount of revenues to the E.U. Treasury and should be included as part of the E.U. social welfare. It is not clear if these fines would more than offset the negative welfare effect on E.U. consumers and member countries.

6. Concluding Remarks

In this paper, we examine the economic effects of tying and other business strategies on consumer benefit and social welfare, focusing particularly on the landmark Microsoft antitrust cases. We develop a system-good model that captures the idiosyncratic characteristics of the operating software monopoly (i.e., Windows dominance) and of the oligopolistic market for application software products. We first analyze competition in the market for two alternative settings according the rules of game set by the antitrust law. The first setting is tying by a dominant firm that integrates its application software with the operating software to form a bundled system good. The second setting is when the dominant firm is broken up into smaller entities. Given the specific vertical structure with an essential component, we show that tying enhances competition in the market for application software products. Tying benefits consumers as they pay lower prices for system goods, regardless of whether the goods are factory-integrated or mixed-and-matched. The dominant firm's integration of application software with its operating software is a socially desirable system good. Breaking up the integrated dominant firm is socially undesirable as it stifles competition and hurts consumer benefits. We further analyze competition for the market when the tying firm and its competitor engage in R&D activities, which are strategically designed to increase their respective positions in the application software market. In the tying *cum* strategic R&D case, we show conflicts between process innovation and market competition. Moreover, we find that the dominant firm is able to exclude its competitor from the market, depending on the degree of product substitutability or the intensity of market competition. The model can also be applied to analyzing international competition and antitrust issues such as the E.U. Microsoft cases.

It is a traditionally held view that business strategies such as tying arrangements, vertical mergers, and exclusionary dealing contracts are serious instruments for exclusion of competitors. Our simple model suggests that tying arrangements or vertical mergers tend to enhance competition. But strategic R&D investments or exclusionary dealing contracts tend to stifle competition. Thus, there are differences between these two categories of business strategies that may warrant different treatment in antitrust analysis. This appears to be consistent with the arguments made by Posner (1976, p. 197). It should also be mentioned that there were debates about whether antitrust policies should be applied to innovative industries. The major concern is that the structure of firms in these industries is changing dynamically but the antitrust policies designed to discipline industries are static. Our simple analysis suggests that asymmetric vertical market structure (e.g., the operating software monopoly plus the oligopolistic application software market) and the nature of product components in system goods for final consumption should be taken into consideration in deciding whether a dominant firm's conduct is in violation of the antitrust laws.

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