Does Microsoft Stifle Innovation? Dominant Firms, Imitation, and R&D Incentives

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Abstract

We provide a simple framework with which to analyze the impact of firm dominance on incentives for R&D. We consider two sources of firm dominance: either the dominant firm adds b to its product value or it reduces the value of the rival's product by d. We show that an increase in b or d increases the dominant firm's innovation incentives and decreases the rival's. If imitation is easy, then the latter effect dominates and welfare is decreasing in the extent of firm dominance. If imitation is difficult, an increase in firm dominance may increase overall innovation incentives to the extent that welfare is increasing in b and d.

1 Introduction

Few issues have polarized public opinion as much as the Microsoft antitrust trial. Those siding with Microsoft argue that Microsoft is a victim of its own success:

> In the pending actions against Microsoft, Microsoft is accused of improving their products in such a way that they force out their competition ... But isn't improving their products just what we want companies to do? Isn't offering consumers more for less money ... the sort of behavior we would expect from a competitive firm? (FreeMarket.net, undated)

A criticism of this view is that Microsoft is not really creating value but rather appropriating value:

> Microsoft has rarely been the innovator ... Excel, the Microsoft spreadsheet, is an imitation of Lotus 123, which was in turn an imitation of VisiCalc ... Microsoft Word was introduced into the market long after several other popular word processors. Microsoft's Power Point imitated programs such as Harvard Graphics or Freelance, and Microsoft used acquisitions to buy itself into the relational database market, where it was a late entrant. (Nader and Love, 1997)[1]

One critic goes to the extreme of describing Microsoft's strategy as "Copy and Conquer" (Kostura, undated). In terms of consumer and social welfare, the problem with this is that it may reduce the incentives for rival firms to innovate in the applications software market. The previous quote continues as follows:

> While Microsoft was typically late for the dance, it rarely left empty-handed. Today, Microsoft so completely dominates each of these markets that few venture capitalists would even consider

[1] See also "Not Invented Here" (available at http://www.vcnet.com/bms/departments/notinvented.html).

> funding new programs that would seek to dislodge it. Microsoft is not only successful, it seems unbeatable in the PC applications markets. (Nader and Love, 1997)

Notwithstanding the abundance of opinions from the popular press, there has been relatively little economics research on the welfare effects of firm dominance in R&D intensive industries. As Economides (2001) put it,

> on the issue of innovation, economists' opinions are split on whether monopoly or competition would create more innovation. Economists' opinions are also split on whether vertically integrated or independent companies create more innovation.

Our purpose in this paper is to provide a simple framework with which to analyze the impact of firm dominance on incentives for R&D. We consider a model where two firms invest in R&D with the goal of finding a product of higher quality. Specifically, we consider a two-stage model comprising R&D competition and price competition. Our model has two important features. First, we assume that property rights are imperfect, so that a lagging firm can (imperfectly) imitate the leader. Second, we assume that one of the firms is dominant, in the sense that, everything else constant, its product is worth more in the eyes of consumers.

The dominant firm's product can be superior for two reasons, both of which are considered in the paper. First, the dominant firm may be able to increase the value of its product with respect to what it would be if it were not dominant. Second, the dominant firm may be able to reduce the value of the rival firm's product. To continue with our motivating example, the idea is that, by controlling the operating system and other applications, Microsoft is better able to integrate each piece in the whole PC/Windows platform;[2] but it may also prevent rival firms from integrating their software with the Windows operating system.[3]

[2] In the words of Jim Allchin, Senior Microsoft Vice President,"innovation through integration is the engine that drives the computer industry, bringing the benefits of computing to hundreds of millions of people." See http://www.actonline.org/pubs /hostage/hostage101.asp January 27, 1999.

[3] "Microsoft has ... engaged in practices which are often described as ... anti-competitive, such as the continual manipulation of the proprietary operating system to

We consider the impact of changes in firm dominance on consumer surplus and on social welfare. This dual approach is motivated by the positive fact that public policy frequently puts more weight on consumer surplus; and the normative fact that, in an economy with a distortionary tax system, it is optimal to maximize a weighted welfare function with greater weight on consumer surplus.

Our results suggest that, as one of the firms becomes more dominant, its innovation incentives increase, while the rival firm's incentives decrease. If imitation is easy, then the latter effect outweighs the former; and both consumer welfare and social welfare are decreasing in the degree of firm dominance. If, however, imitation is difficult (and the degree of firm dominance small), then the effects of an increase in firm dominance on innovation incentives cancel out and only the direct effect of firm dominance counts; it follows that consumer and social welfare are increasing under value-increasing dominance and decreasing under value-decreasing dominance.

Although value-increasing dominance is better than value-decreasing dominance, the impact on consumer and social welfare is not clear. Specifically, we show that value-increasing dominance may decrease social welfare and value-decreasing dominance may increase social welfare.

2 Model

Suppose that two firms, 0 and 1, simultaneously invest in R&D. In order to achieve a probability of success r_i a firm must pay a cost $\frac{1}{2}r_i^2$. If successful (probability r_i), firm i gets a product of quality q_H. If unsuccessful (probability $1 - r_i$) firm i's product is worth q_L. Let $g \equiv q_H - q_L$ be the gain from technical progress.

Consumers are willing to pay q_1 for firm 1's product and $q_0 + b$ for firm 0's, where q_i is firm i's quality level. After learning the value of q_i, each firm has the option of imitating its rival. By imitating firm j, firm i's quality

undermine rival's products, selective dissemination of information regarding the operating system's current and future functionality, ... pre-announcements of non-existent products to discourage consumer purchases of rival goods (sometimes referred to as "vaporware")" (Nader and Love, 1997).

Table 1: Timing of the model.

1.	Firms simultaneously invest in R&D.
	• Firms observe R&D outcome.
	• Laggard imitates leader (if applicable).
2.	Firm simultaneously set prices.
	• Consumer chooses one of the firms and buys one unit.

Table 2: Notation.

q	Quality level
g	Innovation gain: $g \equiv q_H - q_L$
l	Imitation lag
b	Firm 0's extra value
r_i	Firm i's level of R&D, $i = 0, 1$
V_i	Firm i's expected value, $i = 0, 1$
CS	Consumer surplus
SW	Social welfare

becomes $q_i = q_j - l$. The value of l measures imitation lags.

Once the values of q_i have been determined (including, possibly, imitation), firms compete in prices. For simplicity, we assume there is one consumer buying one unit from one of the firms, whichever firm maximizes the difference between valuation and price.

Throughout the paper, we assume that b is lower than l and l lower than g. This implies that it is optimal for a firm with a lower interim q to imitate its rival. We therefore simplify the second stage of the game by assuming that, in case only one firm is successful in R&D, the unsuccessful firm imitates the successful one.

The timing of the game, summarized in Table 1, is as follows. Table 2 lists the model's notation.

As usual, we solve the game backwards, beginning with the second-stage

Table 3: Consumer surplus, social surplus and firm gross profit as a function of R&D outcome.

Willingness to pay for Firm 0

	S_1	N_1
S_0	$q_H + b$	$q_H + b$
N_0	$q_H - l + b$	$q_L + b$

Willingness to pay for Firm 1

	S_1	N_1
S_0	q_H	$q_H - l$
N_0	q_H	q_L

Price

	S_1	N_1
S_0	b	$l + b$
N_0	$l - b$	b

Firm 0's profit

	S_1	N_1
S_0	b	$l + b$
N_0	0	b

Firm 1's profit

	S_1	N_1
S_0	0	0
N_0	$l - b$	0

Consumer suprlus

	S_1	N_1
S_0	q_H	$q_H - l$
N_0	$q_H - l + b$	q_L

Social surplus

	S_1	N_1
S_0	$q_H + b$	$q_H + b$
N_0	q_H	$q_L + b$

pricing game and then solving the R&D stage. Table 3 summarizes the values of consumer willingness to pay, equilibrium price, firm profit (assuming zero costs), consumer surplus and total surplus, each for all possible outcomes of the R&D process. In each matrix, S_i denotes that firm i succeeds in the R&D stage, N_i the opposite. For example, if Firm 0 is successful (S_0) and Firm 1 is not (N_1), which corresponds to the top right corner of each matrix, then:

- Consumer willingness to pay for Firm 0's product is $q_H + b$;
- Consumer willingness to pay for Firm 1's product is $q_H - l$;
- In the pricing stage, $p_0 = l + b$ and $p_1 = 0$;
- Firm 0's profit is $l + b$;
- Firm 1's profit is zero;
- Consumer surplus is $q_H + b - (l + b) = q_H - l$;
- Social surplus is $q_H + b$.

More generally, equilibrium prices are as follows: the firm with higher willingness to pay sets a price equal to the difference to the willingness to pay for the rival's product; the rival firm, in turn, sets price equal to zero. In equilibrium, consumers choose the firm charging a positive price (which we designate as equilibrium price). Consumer surplus is the difference between willingness to pay and price for the firm with higher willingness to pay; and social surplus is willingness to pay for the firm with higher value of willingness to pay.

Notice that Firm 0 makes a sale in all cases but (N_0, S_1). Based on this, we can arrange terms and express Firm 0 and Firm 1's expected values as

$$\begin{aligned} V_0 &= b\Big(1 - (1 - r_0)\, r_1\Big) + l\, r_0\, (1 - r_1) - \frac{1}{2} r_0 \\ V_1 &= (l - b)\,(1 - r_0)\, r_1 - \frac{1}{2} r_1. \end{aligned} \tag{1}$$

Expected consumer surplus is given by (recall that $g \equiv q_H - q_L$)

$$CS \equiv q_L + r_0 r_1 g + (1 - r_0) r_1 (g - l + b) + r_0 (1 - r_1)(g - l).$$

Finally, expected social welfare is given by

$$SW \equiv q_L + r_0 r_1 (g+b) + (1-r_0) r_1 g + r_0 (1-r_1)(g+b) + (1-r_0)(1-r_1) b - r_0^2/2 - r_1^2/2.$$

We make the following assumption regarding the values of b, l and g:

Assumption 1 $\quad b < l < 1.$

Assumption 2 $\quad g > 1.$

Assumption 1 implies that the solution is interior. If $b > l$ or $l > 1$, then we get a corner solution and changes in b have no impact on the equilibrium values of r_i. Assumption 2 reflects the idea that innovation is important. In the limit when g is very small, innovation is unimportant and the only effect of a change in b is the direct effect.

3 Firm dominance and R&D incentives

Our main goal is to examine the impact of firm dominance on innovation incentives. We will do so by looking at the impact of a small increase in b. If $b = 0$, then the two firms are symmetric. As we increase the value of b, one of the firms (Firm 0) becomes a dominant firm.

4 Consumer surplus

What is the impact of an increase in b on consumer surplus? The first step is to look at the *direct* effect of an increase in b, that is, the effect of an increase in b holding the values of r_i constant. The direct effect of an increase in b is given by the partial derivative of CS with respect to b. We then have:

$$\frac{\partial\, CS}{\partial\, b} = (1 - r_0)r_1.$$

This makes sense. From Table 3, we can see that the only state when b matters for consumers is (N_0, S_1), which happens with probability $(1-r_0)r_1$. In all other cases, the dominant firm wins the sale and increases consumer price to the extent of b, so that consumers benefit nothing from an increase in b.

Let us now consider the *total* effect of an increase in b. Define $CS^e \equiv CS(r_0^e, r_1^e)$, where r_i^e is the equilibrium value of r_i. The total effect of a change in b is then given by $\frac{d\,CS^e}{d\,b}$. Let us start by considering the results from numerical analysis for a particular value of g.[4] Figure 1 divides the (l, b) space into regions according to the sign of $\frac{d\,CS^e}{d\,b} > 0$. Except for the small region by the l axis, this derivative is negative. Figure 1 suggests that, for high values of l (strong patents, or difficult imitation), the derivative of consumer surplus with respect to b is first positive, then negative. Is this a general result? The answer is affirmative:

Proposition 2 *For low values of l, consumer surplus is maximal with $b = 0$. For high values of l, consumer surplus is maximal with an intermediate value of b.*

The formal proof may be found in the appendix. In what follows, we provide the intuition for why the impact of an increase in b is negative when l is small and positive when l is large (and b small). Define

$$\begin{aligned}
P_{one} &\equiv 1 - (1 - r_0)(1 - r_1) - r_0 r_1 \\
P_{two} &\equiv r_0 r_1 \\
P_{rival} &\equiv (1 - r_0)r_1.
\end{aligned}$$

[4] Our results, however, are based on analytical proofs.

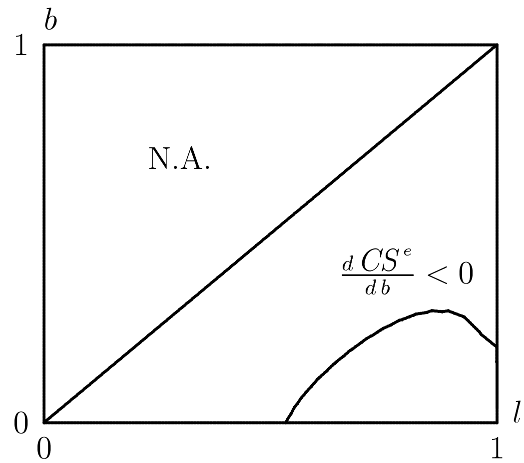

Figure 1: Results of numerical analysis ($g = 2$).

P_{one} is the probability that exactly one firm innovates; P_{two} is the probability that two firms innovate; P_{rival} is the probability that only the rival firm innovates. Consumer surplus can then be written as

$$CS = q_L + (g - l)\, P_{one} + g\, P_{two} + b\, P_{rival}\,.$$

In words, this implies that there are four effects of b on CS, one direct and three indirect:

- Direct effect. This is proportional to $P_{rival} \equiv (1-r_0)r_1$. It corresponds to the case when Firm 0 limits the extent to which Firm 1 can raise price. In other words, a greater b protects consumers in the case when Firm 1 is the only successful firm.

- Strategic effect, I: change in P_{one}. An increase in P_{one} implies that the probability one firm only is successful is greater. This implies a gain of $g - l$ to consumers.

- Strategic effect, II: change in P_{two}. An increase in P_{two} means that the probability of innovation by both firms is greater. This has a benefit of g for consumers.

- Strategic effect, III: change in P_{rival}. If the single innovator turns out to be Firm 1, then consumers get an extra benefit given by b: the dominant firm will limit Firm 1's market power.

For low values of b, l we have $r_0 \approx r_1 \approx 0$. It follows that the direct effect, the second strategic effect, and the third strategic effects are all of second order. In turn, the first strategic effect is given by

$$(g-l)\frac{\partial P_{one}}{\partial b} \approx (g-l)\frac{\partial (r_0 + r_1)}{\partial b}.$$

We know from Proposition 1 that r_0 is increasing and r_1 decreasing in b. Which of the two variations dominate? In order to answer this question, we look at the effect of an increase in b on each firm's first-order condition. From (1), we get

$$\begin{aligned} \frac{\partial^2 V_0}{\partial r_0 \, \partial b} &= r_1 \\ \frac{\partial^2 V_1}{\partial r_1 \, \partial b} &= -(1 - r_0). \end{aligned} \tag{2}$$

This implies that, for l close to zero, the impact of a small increase in b from $b = 0$ is of first-order in the case of r_1 but only second-order in the case of r_0.

Still another way of understanding this intuition is to consider the profit matrices in Table 3. If $r_i \approx 0$, then the outcome from R&D is most likely to fall in the bottom right cell (N_0, N_1). The marginal R&D incentive for Firm 0 is then to move from (N_0, N_1) to (S_0, N_1). But Table 3 suggests that an increase in b does not change this marginal gain: Firm 0 gets b regardless of whether it innovates or not. In other words, b is a windfall gain for Firm 0. The same is not true for Firm 1. The greater b is the lower the incrementa gain from moving to (N_0, S_1). To summarize: an increase in b is bad because it rewards Firm 0 but does not create any extra innovation incentives for Firm 0; moreover, it punishes Firm 1 *and* decreases Firm 1's innovation incentives.

Consider now the case when l is close to one, whereas b is close to zero. Substituting $l = 1, b = 0$ into (1) implies $r_0^e = r_1^e = \frac{1}{2}$. Moreover, by (2)

we know that, at the margin, the positive impact on r_0 of an increase in b is approximately equal to the negative impact on r_1. This implies that the strategic effects through P_{one} and P_{two} are both zero. The effect of a increase in b on P_{rival} is non-zero, but P_{rival} multiplies b, which is small; it follows that the third strategic effect is also close to zero. Finally, we are left with the direct effect, which is positive.

To summarize: when the value of l is small, an increase in b increases Firm 0's payoff but not its incentives for R&D. It does decrease Firm 1's incentives, resulting in a negative overall effect. When the value of l is large (and b small), an increase in b has positive and negative effects on R&D incentives which cancel out. Overall, an increase in b increases consumer surplus through the direct effect.

5 Social surplus

In the previous section, we looked at the impact of a change in b on consumer surplus. We now consider the impact of b on social welfare. As before, we start by looking at the direct effect of an increase in b:

$$\frac{\partial SW}{\partial b} = r_0 r_1 + r_0(1-r_1) + (1-r_0)(1-r_1) = 1-(1-r_0)r_1.$$

Intuitively, society always benefits from the dominant firm's extra benefit b except when the rival firm succeeds in R&D and the dominant firm does not, which happens with probability $(1-r_0)r_1$.

Figure 2 depicts the value of $\frac{dSW}{db}$ in the (l,b) space, for a particular value of g. The figure suggests that the derivative is negative for low values of l and positive for high values of l. It also suggests that, for intermediate values of l, the derivative is positive for low values of b and negative for high values of b. In the appendix we prove that this is a general result:

Proposition 3 *For low values of l, social welfare is maximal with $b = 0$. For high values of l, social welfare is maximal with the maximum value of b. For intermediate values of l, social welfare is maximal with an intermediate value of b.*

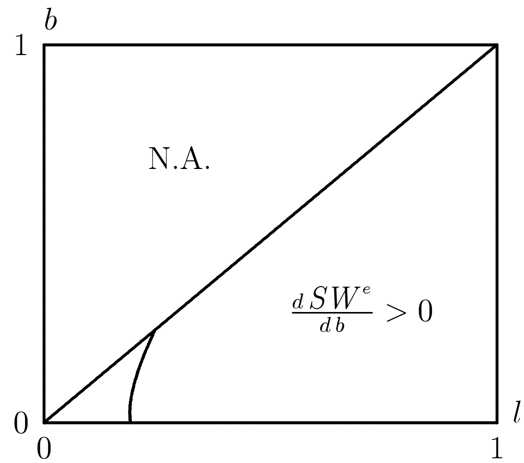

Figure 2: Results of numerical analysis ($g = 2$).

6 Value added vs raising rival's costs

Although most agree that Microsoft has a competitive advantage over rivals, there is wide disagreement as to what the source of such advantage is. So far, we have assumed that Firm 0, the dominant firm, is able to add value to its product. An alternative story would be that Firm 0 is able to lower the rival product's value by d.[5]

Table 4 depicts the values of willingness to pay, price, firm profit, consumer surplus and social welfare under the alternative interpretation of the model. Comparing with Table 3, it is readily apparent that equilibrium price and profits are identical once we change b for d. This is not surprising: since firms compete in price and total demand is inelastic, the only thing that matters is differences in valuation. Whether these differences arise from an increase in Firm 0's valuation or a decrease in Firm 1's valuation is irrelevant.

The difference between b and d is not irrelevant, however, from the perspective of consumer surplus and social welfare. In a sense the impacts are "complementary:" a change in b has an effect on consumer surplus in state (N_0, S_1) and an effect on social welfare in all states but (N_0, S_1). A change in d, by contrast, as an effect on social welfare in state (N_0, S_1) and an effect

[5]A third possibility would be to increase the rival firm's cost. This would lead to the same results in terms of social welfare.

Table 4: Consumer surplus, social surplus and firm gross profit as a function of R&D outcome.

Willingness to pay for Firm 0

	S_1	N_1
S_0	q_H	q_H
N_0	$q_H - l$	q_L

Willingness to pay for Firm 1

	S_1	N_1
S_0	$q_H - d$	$q_H - l - d$
N_0	$q_H - d$	$q_L - d$

Price

	S_1	N_1
S_0	d	$l + d$
N_0	$l - d$	d

Firm 0's profit

Firm 1's profit

S_1 N_1

on consumer surplus in all states but (N_0, S_1).

Not surprisingly, from the point of view of consumer and social welfare dominance by "damaging" the rival's product is less attractive than dominance by increased value. In fact, it can be shown that consumer surplus is everywhere decreasing in d. What is perhaps surprising is that social welfare may be greater with a high value of d then with $d = 0$:

Proposition 4 *For low values of d, an increase in d implies a decline in social surplus. However, for high values of l social surplus is greater with d=l than with d=0.*

The intuition for low values of d is similar to the comparative statics of consumer surplus with respect to changes in b. If l is close to zero, then the only effect of an increase in d is to encourage the dominant firm and discourage the rival firm from performing R&D; and the effect on the rival firm is one order of magnitude greater than the effect on the dominant firm. If, at the other extreme, l is close to one, then the strategic effects on each firm's R&D levels cancel out; the only effect that is left is the direct effect, which, unlike the increase in b, is negative.

In order to understand the intuition for the second part of the proposition, suppose that $l \approx 1$. If $d \approx 1$, then we are close to the corner solution $r_0 = 1, r_1 = 0$. In this situation, d has no direct effect on social welfare. The only state when d enters social welfare, (N_0, S_1), happens with very low probability. The only effect of d is therefore the strategic effect: to shift R&D effort from the rival to the dominant firm, from $r_0 = r_1 = \frac{1}{2}$ to $r_0 = 1, r_1 = 0$. This is socially beneficial: $r_0 = 1, r_1 = 0$ implies innovation with probability 1, whereas, under the $r_0 = r_1 = \frac{1}{2}$ solution, there is a 25% probability that innovation will not take place. Although total R&D costs are greater with specialization (because R&D costs are convex), $g > 1$ implies that on balance society benefits from specialization.[6]

[6]Specifically, computation implies that

$$SW|_{l=1,d=1} - SW|_{l=1,d=0} = \frac{1}{4}(g-1).$$

7 Extensions

Our basic model can be extended in a number of ways:

- $n > 2$. So far, we have considered the case when there is one firm in addition to firm zero. We conjecture that the negative effect of firm dominance may be amplified if there is more than one rival firm, especially if we consider endogenous entry.

- Bertrand competition. We conjecture that the negative effect of firm dominance is somewhat exarcebated by our assumption of Bertrand competition. However, we would expect the main qualitative results to extend in other contexts. Specifically, it can be shown that, under Hotelling competition with a small transportation cost the results still hold (by continuity).

- R&D cost function. For tractability, we have assumed a simple quadratic R&D cost function. Again, we conjecture that the main qualitative results are robust to changes in the particular functional form.

- The focus of this paper has been on the effects of firm dominance. However, as one of the parameters, l, relates to the strength of property rights, an interesting question is the impact of changes in l on consumer and social welfare. It can be show that, if g is not too large, then consumer surplus is maximal for an intermediate level of l.[7] Numerical simulations suggest that social welfare is everywhere increasing in l (but we have not been able to find an analytical proof yet).

[7] Computation establishes that

$$\begin{aligned} \left.\frac{\partial\, CS}{\partial\, l}\right|_{l=0} &= 2g \\ \left.\frac{\partial\, CS}{\partial\, l}\right|_{l=1} &= \frac{g-2-b(1-b)}{b(2-b)}, \end{aligned}$$

where, by Assumption 1, we assume $b = 0$ when $l = 0$. The first derivative is positive. If $g < 2$, then the second derivative is negative for all b.

8 Concluding remarks

In reference to the Microsoft case, Barro (1998) argued that

> In capitalism, which works better than any other known economic system, the reward for delivering good products at low costs is large profits. To secure these profits, businesses typically have to innovate in ways that lead temporarily to monopoly power over new products or methods of production. In a well-functioning free enterprise system, businesses must be allowed to enjoy these profits. This incentive principle is recognized, for instance, in the patent system for inventions. But the idea has much broader applications, and the government should not step in to limit profits at the first sign of monopoly power.

Our paper takes this "agnostic" position and reaches some interesting conclusions. If imitation is difficult, then firm dominance may be good for consumers and society because a dominant firm provides better integration without discouraging overall innovation (it does however shift innovation from the rival firm to the dominant firm). In fact, even if dominace is achieved by lowering the rival firm's product value, dominance may increase social welfare because it increases overall innovation. If imitation is easy, however, then firm dominance does more harm than benefit: it discourages innovation by rival firms without bringing significant benefits to consumers.

Should Microsoft be broken up? Steve Ballmer claims that "a breakup of Microsoft, I think, would be an awful thing for consumers and for the industry. The real issue in a possible breakup would be the harm it does to innovation."[8] Our results suggest that a breakup would indeed reduce innovation by Microsoft. As to whether consumers and the industry would benefit, the answer is not so obvious.

[8] See http://www.wired.com/news/politics/0,1283,36819,00.html

Appendix

Proof of Proposition 1: Taking the derivatives of V_i with respect to r_i and solving with respect to r_i we get the following best-response functions:

$$\begin{aligned} r_0^* &= l-(l-b)r_1 \\ r_1^* &= (l-b)(1-r_0). \end{aligned}$$

Solving for the Nash equilibrium, we get

$$\begin{aligned} r_0^e &= \frac{l-(l-b)^2}{1-(l-b)^2} \\ r_1^e &= \frac{(1-l)(l-b)}{1-(l-b)^2}. \end{aligned}$$

Our goal is to study the impact of changes in b. It can be seen that

$$\begin{aligned} \frac{d\,r_0^e}{d\,b} &= 2\frac{(1-l)(l-b)}{(1-(l-b)^2)^2} \\ \frac{d\,r_1^e}{d\,b} &= -\frac{(1-l)(1+(l-b)^2)}{(1-(l-b)^2)^2}, \end{aligned}$$

which implies the result. ■

Proof of Proposition 2: Computing the derivative of CS^e with respect to b and equating b to zero we get

$$\left.\frac{d\,CS^e}{d\,b}\right|_{b=0} = \frac{2l-l^2(1-l)-g(1-l)}{(1+l)^3}.$$

Immediate inspection reveals that the derivative ranges from $-g<0$ for $l=0$ to $\frac{1}{4}>0$ for $l=1$. Moreover, the derivative of the numerator with respect to l is given by $3l^2+2(1-l)+g$, which is positive under Assumption 1. It follows that, for small values of b, there exists an $\bar{l}(b)$ such that consumer surplus is decreasing in b if and only if $l<\bar{l}(b)$.

Consider now the case when $b = l$. Computation establishes that

$$\left.\frac{d\,CS^e}{d\,b}\right|_{b=l} = -(1-l)\left(g(1-l)+l^2\right) < 0.$$

Together with the previous result, this implies that for high values of l, consumer surplus is maximal for an intermediate value of b. ■

Proof of Proposition 3: Define $SW^e \equiv SW(r_0^e, r_1^e)$. Computing the derivative of SW^e with respect to b and equating b to zero we get

$$\left.\frac{d\,SW^e}{d\,b}\right|_{b=0} = \frac{1+3l+l^2(1+l)-g(1-l)}{(1+l)^3}.$$

Immediate inspection reveals that the derivative ranges from $1-g<0$ for $l=0$ to $\frac{3}{4}>0$ for $l=1$. Moreover, the derivative of the numerator with respect to l is given by $3+2l(1+l)+l^2+g$, which is positive. It follows that, for small values of b, there exists an $l_1(b)$ such that social welfare is increasing in b if and only if $l > l_1(b)$.

For high values of b ($b \approx l$), there exists an $l_2(b)$ such that social welfare is increasing in b if and only if $l > l_2(b)$.

Painful but otherwise uneventful computation reveals that

$$\left.\frac{d\,SW^e}{d\,b}\right|_{b=0} > 0 \Rightarrow \left.\frac{d\,SW^e}{d\,b}\right|_{b=l} > 0.$$

This implies that, for intermediate values of l, social welfare is maximal for an intermediate value of b. ■

References

Note: the following list of references is vastly incomplete. It is limited to the sources of quotes included in the introduction. A literature review and additional references will be included in a later version of the paper.

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