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Competition or Predation? Schumpeterian Rivalry in Network Markets

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Abstract:

We explore the logic of predation and rules designed to prevent it in markets subject to network effects. Although, as many have informally argued, predatory behavior is plausibly more likely to succeed in such markets, we find that it is particularly hard to intervene in network markets in ways that improve welfare. We find that imposition of the leading proposals for rules against predatory pricing may lower or raise consumer welfare, depending on conditions that may be difficult to identify in practice.

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This paper is available on-line at <http://www.haas.berkeley.edu/groups/cpc/pubs/Publications.html>

In some ways, software is the perfect market for predatory pricing.

—Garth Saloner

If Microsoft enters a new market and competes aggressively by giving away its software, God bless them.

—Carl Shapiro¹

I. INTRODUCTION

Predatory behavior has long been a contentious issue. Schematically, predatory behavior can be thought of as occurring in two phases. In the *predation phase*, the predatory firm offers a product that offers “too much” value to consumers (*e.g.*, the price is too low, the quality is too high, or the product is too innovative) and thus weakens rivals. In the *recoupment phase*, the predator takes advantage of the fact that its rivals have been weakened and reduces the value its product offers to consumers to a level below the competitive one.

Economists and the courts have been skeptical of claims of predation in traditional markets for several reasons.² First, during the predatory phase, consumers often gain from the intense rivalry, even if it is conducted with predatory intentions.³ Second, many have questioned whether rivals will remain weakened in the recoupment stage. If rivals can bounce back, then predation will be unprofitable and consumers would suffer no second-stage welfare losses even if a firm irrationally engaged in predation. Lastly, it may be difficult to distinguish harmful predation from beneficial competition.⁴

¹ Both quotations are from Mike France and Steve Hamm, “Does Predatory Pricing Make Microsoft a Predator?” *Business Week*, November 23, 1998, at 132.

² For a useful summary of the economic and legal opinions regarding predation, see Brodley *et al.* (2000). Brodley and his co-authors argue that courts are skeptical of predation because the courts are ignorant of modern economic theory.

³ As Cabral and Riordan (1997) demonstrate, consumers do not always gain during the predatory phase.

⁴ Indeed, rivals may use claims of predation as attempts to limit competition. There is an old joke about the verb conjugated “I compete, *you* predate.”

Largely because of the visibility of *U.S. v. Microsoft*, issues of predation in network markets have recently been in the spotlight. Network effects arise when, the greater the number of users on a system, the more valuable the system is to an individual user.⁵ Such positive feedback is a common feature of communications networks such as voice telephony, e-mail, and video conferencing. Network effects also can arise when a system consists of two components produced separately and used together, such as a computer operating system and applications programming. Positive feedback arises if there are economies of scale in the provision of applications programs, so that a larger installed or anticipated base for the operating system makes additional entry in applications programming profitable, generating benefits for consumers. Other examples include credit cards and the merchants that accept them, and digital television broadcasts and television sets that can receive them.

One school of thought holds that network effects make acts aimed at weakening competition more likely to succeed and more harmful. Proprietary network effects can indeed create a durable advantage for a predator, preventing the prey from returning to its full competitive prowess once the recoupment period begins. This view is, however, incomplete in two significant respects. First, one must examine the possibility that the prey might resist predation more vigorously and/or successfully in markets with network effects. Second, even if successful predation is likely, it does not follow that public policy should intervene in network markets to prevent predation. Distinguishing competition from predation may be even more difficult in network markets than in others. With intertemporal increasing returns, there may innocently be intense initial competition as firms fight to make initial sales and benefit from the increasing returns. Moreover, because of increasing returns, network markets may be subject to

⁵ For a survey of the economics of network effects, see Katz and Shapiro (1994).

“tipping,” in which one firm makes all the sales in a given period. This tipping can be economically efficient. For example, it may raise welfare by increasing network benefits through *de facto* standardization.⁶

In network markets subject to technological progress, competition may take the form of a succession of “temporary monopolists” who displace one another through innovation. Such competition is often called *Schumpeterian rivalry*. Some have asked: If the market at any point will be monopolized anyway, why should we care who the monopolist is or what it did to become and remain the monopolist?⁷ The answer, of course, lies in understanding the welfare effects of various modes of competition to be the monopolist *du jour*.

In this paper, we use a simple two-period model to analyze potential public policy intervention in markets characterized by significant network effects. In our model, all consumers in a given period join the same network, but one network may displace another over time, perhaps through innovation.⁸ Predation can be an equilibrium strategy in this model, but we find that rules against below-cost pricing and other allegedly predatory behavior can harm welfare by preventing firms from internalizing the benefits of increasing returns to scale.⁹ Such rules may also perform poorly in Schumpeterian contexts.

⁶ The new joke may be “I *internalize*, you predate.”

⁷ This question was raised by the appellate court in the February 2001 oral argument of *U.S. v. Microsoft*. Transcripts are posted *e.g.* at <http://www.microsoft.com/presspass/trial/transcripts/>.

⁸ In our model, innovation (change in a firm’s unit costs) is exogenous. We hope that future research will endogenize innovation.

⁹ Cabral and Riordan (1994 and 1997) reached similar conclusions for markets that exhibit experience effects, whereby greater past sales translate into lower current production costs through the accumulation of experience. Experience and network effects are both sources of inter-temporal increasing returns to scale. However, equilibrium dynamics—particularly the role of consumer expectations—can be very different. In markets subject to network effects, consumers may have to form expectations about *future* sales. No such effects arise in standard models of markets with learning by doing.

The paper is organized as follows. The next section presents a simple multistage model of a network industry, and analyzes competition when products are compatible. Most of the paper addresses incompatible competition, with and without price floors. Section III presents some general results. Sections IV and V examine the effects of two leading proposals for rules against predatory behavior: Areeda-Turner cost-based floors and Ordoover-Willig counterfactual-based floors. Section VI briefly examines the effects of price floors on non-price conduct, including compatibility choice. The paper closes with a short conclusion. A technical appendix offers an alternative interpretation of the model.

II. THE MODEL AND PRELIMINARIES

In this section, we describe the model and characterize equilibrium under compatibility.

A. The Set-Up

We examine subgame-perfect equilibria of the following three-stage game between two firms, X and Y , offering competing products also labeled X and Y .¹⁰ The timing is as follows:

- At time zero, the firms choose whether to make their products compatible with one another.
- In period one, each firm sets the price for its first-period product, denoted p_1 and q_1 , respectively. N consumers then each independently choose which product to buy.
- In period two, each firm sets its second-period price, denoted p_2 and q_2 , and N additional consumers choose which product to buy.

Each consumer buys one unit of the good and derives gross benefits $v(z)$, where z is the total number of consumers (in both periods combined) who purchase units compatible with hers.¹¹ Other than possible differences in network benefits, the two products are homogeneous.

¹⁰ This is a modified version of the model developed in Katz and Shapiro (1986b).

¹¹ We assume throughout that each firm's first-period and second-period products are compatible with one another.

Product X has constant unit costs c_t in period t , while product Y has constant unit costs, d_t . Let $\alpha_t = d_t - c_t$ denote the cost *advantage* enjoyed by firm X in period t , and label the firms so that $\alpha_1 \geq 0$.¹²

B. Constrained Welfare Optima

As a baseline, suppose that consumers can be assigned to a supplier by fiat and consider the welfare optimum. For reasons that will become clear, make the additional assumption that all consumers in a given cohort must be assigned to the same supplier.

When the products are compatible, gross consumption benefits are $2Nv(2N)$ regardless of the networks to which consumers are assigned. Hence, welfare is maximized by having each cohort purchase from the firm that has lower costs in the respective period.

Now, suppose that the two products are incompatible. If all consumers in both periods purchase the same product, maximal welfare per capita is

$$v(2N) - \min\{c_1+c_2, d_1+d_2\}/2 ,$$

and the choice of supplier is made by looking at the average cost over the two periods: X is chosen if and only if $\alpha_1 + \alpha_2 \geq 0$. When $\alpha_1 > 0 > \alpha_2$, it may be socially optimal to split the cohorts, yielding average per-capita welfare

$$v(N) - (c_1 + d_2)/2 .$$

(By our labeling convention, $\alpha_1 \geq 0$ and, thus, if the two cohorts are split, first-period consumers are assigned to firm X .) Hence, keeping the consumers together is optimal if and only if:

$$\beta \geq \min\{\alpha_1, -\alpha_2\}/2 , \tag{1}$$

¹² If the products were to differ in quality rather than in cost, the analysis would be identical to the present model if all consumers had the same valuation of incremental quality.

where $\beta \equiv v(2N) - v(N)$. The left-hand side of inequality (1) is the increase in network effects from togetherness, and the right-hand side is the sacrifice in terms of higher costs.

C. Equilibrium with Compatible Products

Suppose the products are compatible. We examine equilibria in which every consumer buys one unit of the good, and a consumer enjoys gross benefits of $v(2N)$ no matter which technology she purchases.¹³ Hence, we have a standard two-period Bertrand game between undifferentiated competitors. It is easily shown that in each period the firm with the lower costs makes all of the sales at a price equal to the unit costs of the other firm. Hence, equilibrium industry profits are $N \times \{|\alpha_1| + |\alpha_2|\}$, consumer surplus is $N \times \{2v(2N) - \max\{c_1, d_1\} - \max\{c_2, d_2\}\}$, and total surplus is $N \times \{2v(2N) - \min\{c_1, d_1\} - \min\{c_2, d_2\}\}$. Compatibility yields the first-best outcome: network benefits are maximized and production costs are minimized.¹⁴

Costs in one period do not depend on pricing or sales in the other period. And, under compatibility, the network effects are shared by both firms. Hence, reducing a rival's first-period sales does not weaken its second-period ability to compete. Nor can a firm improve its own second-period offering by making more first-period sales. So there is no incentive for below-cost pricing, either to predate or as an innocent investment in installed base.

III. EQUILIBRIUM WITH INCOMPATIBLE PRODUCTS

With incompatible products, individual firms' network sizes matter and there are demand-side intertemporal linkages. Reducing a firm's first-period sales can reduce its ability to compete later, creating the possibility of predatory behavior. With incompatible products,

¹³ $v(0) > \min\{c_t, d_t\}$ for $t = 1, 2$ ensures that all consumers purchase in any equilibrium.

¹⁴ In more general settings, incompatibility may be preferable because it places fewer restrictions on product development or it avoids a commons problem that would reduce incentives to invest in the joint network.

however, equilibrium can also entail below-cost first-period pricing for innocent reasons, so the problem of distinguishing predation from competition arises.

Competition between incompatible networks also introduces another complication to the analysis. The expected consumer benefits from a first-period purchase of firm Z 's product depend on beliefs about Z 's second-period sales.¹⁵ Moreover, a consumer in either period must form beliefs about the purchase decisions of his or her cohort.

A. Second-Period Equilibrium

As usual, we solve the game working backwards in time to find fulfilled expectations equilibria that do not involve incredible threats or promises. We start by solving for equilibrium prices and quantities in the second period conditional on first-period sales. Given assumptions made below concerning first-period consumers, there are two possible histories: Either firm X makes all of the first-period sales or Y does.

Given consumer homogeneity and network effects, only equilibria in which all consumers within the second period purchase the same product are stable, and we focus solely on these outcomes. However, because of network effects, there may be two second-period adoption equilibria. Specifically, let S denote firm X 's first-period sales. Multiple equilibria arise when $v(S+N) - v(N-S) > p_2 - q_2 > v(S) - v(2N-S)$ because each second-period consumer would want to match the other members of his or her cohort whether they all bought X or all bought Y .¹⁶ There must be some equilibrium selection rule. We assume that second-period consumers follow a cutoff rule, where the cutoff may vary with the history of the game:

¹⁵ We assume that transactions costs prevent firms from offering contracts that make prices contingent on network sizes.

Assumption 1: *Suppose the products are incompatible and all first-period consumers made purchases from firm Z. Then all second-period customers follow the same cutoff rule: purchase from X if and only if $p_2 \leq q_2 + \gamma_Z$.*

Here, γ_Z is firm X's second-period demand-side advantage when firm Z won first-period sales.

If and only if $\gamma_X \in [0, \delta + \beta]$ and $\gamma_Y \in [-(\delta + \beta), 0]$, such cutoff rules are consistent with rational consumer behavior. To see this, consider an arbitrary cutoff value, γ_0 . Suppose firm X won the first period and a second-period consumer expects all other cohort members to follow the rule *purchase X if and only if $p_2 \leq q_2 + \gamma_0$* . If $p_2 \leq q_2 + \gamma_0$, purchasing X yields expected surplus $v(2N) - p_2$, while Y yields $v(0) - q_2$. If $p_2 > q_2 + \gamma_0$, purchasing X yields expected surplus $v(N) - p_2$, while Y yields $v(N) - q_2$. Hence, if and only if $\gamma_0 \in [0, \delta + \beta]$, the second-period consumer should also use the cutoff rule $\gamma_X = \gamma_0$. Similar calculations establish the range of γ_Y . Note that consumer rationality alone implies $\gamma_X \geq \gamma_Y$: Winning first-period sales improves a firm's second-period position.

The following examples illustrate some plausible expectations processes and the cutoff rules that they generate:

- *Optimal Coordinators:* One possibility is that, when there are multiple equilibria, each second-period consumer believes that all her contemporaries will identify their Pareto-preferred outcome as the focal point. Such “optimal coordinators” buy from X in the second period if and only if $v(S+N) - p_2 \geq v(2N-S) - q_2$, so $\gamma_X = \beta$ and $\gamma_Y = -\beta$. β is the installed *b*ase advantage (measured in terms of incremental surplus that can be offered to consumers) enjoyed in the second period by the firm that made first-period sales.

¹⁶ Suppose firm X has won first-period sales. If $v(N) \leq c_2$ and $v(0) \leq d_2$, then there exists a fulfilled expectations equilibrium in which no second-period sales are made. A similar condition holds for

- *Lagged Expectations:* Consumers may be unable to coordinate on the optimal equilibrium and may instead rely on other focal points. One intuitive possibility is that each second-period consumer expects the firm that won first-period sales to also win second-period sales: Each compares $v(2S) - p_2$ with $v(2(N-S)) - q_2$. Thus, $\gamma_X = \delta + \beta$ and $\gamma_Y = -(\delta + \beta)$, where $\delta \equiv v(N) - v(0)$.
- *Stubborn Expectations:* Consumers might coordinate on focal points based on perceptions of the competing firms' strengths beyond their current product offerings. Such expectations might favor a firm that is well financed or has a strong reputation for product-market success.¹⁷ Suppose each second-period consumer expects X to win second-period sales as long as that is consistent with consumer rationality. Then he compares $v(N+S) - p_2$ with $v(N-S) - q_2$, so $\gamma_X = \delta + \beta$ and $\gamma_Y = 0$. Similarly, if second-period consumers expect Y to win second-period sales no matter what, then $\gamma_X = 0$ and $\gamma_Y = -(\delta + \beta)$. When consumers simply expect other consumers in their cohort to purchase brand Z , *expectations stubbornly favor firm Z*.¹⁸
- *Expectations Track Prices:* Second-period consumers might coordinate on the lower-priced firm as a focal point, which would always be consistent with consumer rationality.

continuation games in which firm Y has won first-period sales. We ignore these cases.

¹⁷ Katz and Shapiro (1992) show that, if one firm has a sufficient efficiency advantage that it can profitably win a multi-stage adoption battle, then it need not price down to its efficiency advantage, but rather can charge each small "batch" of consumers a price reflecting the network effects. In other words, when no consumer or batch is pivotal, the firm that will win in equilibrium need not offer prices that would make its product more attractive to a single decision-maker on behalf of the entire cohort. This offers a possible explanation (outside our model) for stubborn expectations where they favor the more efficient firm.

¹⁸ These expectations are in the spirit of the expectations process of the same name in Farrell and Katz (1998).

Simple calculations show that, with these expectations, it is rational to buy from firm X if $p_2 < q_2$, regardless of which firm has won the first period. In this case, $\gamma_X = 0 = \gamma_Y$ ¹⁹

Given consumers' cutoff rules, we can now characterize the second-period pricing game. As noted above, we can assume that all first-period consumers bought from one firm. Each firm is willing to price as low as its unit cost to win second-period sales. Suppose floors f_t and g_t are imposed on firms X and Y , respectively, in period t . Firm X wins second period sales if and only if $\max\{c_2, f_2\} - \max\{d_2, g_2\} \leq \gamma_Z$, where Z is the firm that won the first-period sales.²⁰

Lemma 1. *Suppose that $f_2 \leq c_2$ and $g_2 \leq d_2$. The imposition of price floors does not affect the second-period equilibrium conditional on the first-period sales history. Firm X wins second-period sales if and only if $\alpha_2 + \gamma_Z \geq 0$, where Z is the firm that made first-period sales. If X wins the second period, it makes sales at $p_2 = d_2 + \gamma_Z$. If Y wins, it makes sales at $q_2 = c_2 - \gamma_Z$.*

For future reference, label the possibilities identified in Lemma 1 as follows:

- *Anticipated X sales.* If $\alpha_2 + \gamma_Y > 0$ then firm X makes second-period sales regardless of which firm wins in the first period.
- *Second-period matching.* If $\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$, second-period consumers always patronize the same network as first-period consumers.
- *Anticipated Y sales.* If $0 > \alpha_2 + \gamma_X$, then firm Y makes second-period sales regardless of which firm wins in the first period.

Observe that these labels describe types of continuation equilibria, exactly one of which applies for any given pair of values of γ_X and γ_Y , while our earlier discussion of consumer

¹⁹ These expectations are similar to *expectations that track surplus* in the Farrell and Katz (1998) model that allows quality, as well as price, competition.

expectations concerned how consumer coordination affects the values of γ_X and γ_Y .

B. First-Period Equilibrium

Price floors, even at or below unit costs, may affect first-period pricing and the resulting consumer choices. We assume that first-period consumers all follow the same cutoff rule:

Assumption 2: *With incompatible products, all first-period customers follow the same cutoff rule: purchase from X if and only if $p_1 \leq q_1 + \kappa$.*

With second-period matching, the cutoff rule is consistent with first-period consumer rationality if and only if $\kappa \in [-(\delta+\beta), \delta+\beta]$, as can be seen by considering what a consumer will do if he believes that all other consumers in both periods will purchase from firm Y , and similarly for firm X . In the case of anticipated X sales, a first-period consumer knows that X 's network size will be at least N . Hence, the cutoff rule is consistent with first-period consumer rationality if and only if $\kappa \in [0, \delta+\beta]$. Likewise, with anticipated Y sales, $\kappa \in [-(\delta+\beta), 0]$

First-period consumers correctly forecast the second-period equilibrium: they recognize that, if they choose firm Z , then second-period consumers will choose X if and only if $\alpha_2 \geq -\gamma_Z$. However, each first-period consumer must also form expectations about the purchase behavior of other members of his cohort. Again, network effects can give rise to multiple equilibria, and a selection mechanism is needed. We illustrate several possibilities:

- *Optimal Coordinators:* Suppose that first-period consumers are optimal coordinators (with one another, not with second-period consumers). Their cutoff rule depends on second-period consumer behavior—specifically, which of the cases from Lemma 1 holds:

²⁰ We break ties in favor of firm X . Generically, parameter values will be such that there are no ties, and we ignore ties in the cases considered below.

- *Anticipated X sales* ($\alpha_2 + \gamma_Y > 0$). First-period consumers compare $v(2N) - p_1$ with $v(N) - q_1$, and thus $\kappa = \beta$.
- *Second-period matching* ($\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$). First-period consumers make their decisions by comparing $v(2N) - p_1$ with $v(2N) - q_1$, and thus $\kappa = 0$.
- *Anticipated Y sales* ($0 > \alpha_2 + \gamma_X$). First-period consumers compare $v(N) - p_1$ with $v(2N) - q_1$, and thus $\kappa = -\beta$.
- *Stubborn Expectations*: Suppose each first-period consumer expects firm X to win (all other) first-period sales as long as that belief is consistent with consumer rationality.

Again the implied first-period cutoff depends on second-period consumer behavior:

- *Anticipated X sales* ($\alpha_2 + \gamma_Y > 0$). First-period consumers compare $v(2N) - p_1$ with $v(0) - q_1$. Hence, $\kappa = \delta + \beta$.
- *Second-period matching* ($\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$). First-period consumers compare $v(2N) - p_1$ with $v(0) - q_1$. Hence, $\kappa = \delta + \beta$.
- *Anticipated Y sales* ($0 > \alpha_2 + \gamma_X$). First-period consumers compare $v(N) - p_1$ with $v(N) - q_1$. Hence, $\kappa = 0$.

Similar calculations can be made for the case in which first-period consumers expect Y to win the first period.

- *Expectations Track Prices*: Suppose each first-period consumer expects the firm charging the lower first-period price to win. Then $\kappa = 0$ regardless of the second period regime, because first-period consumers believe that the firm with the lower first-period price will always have a network at least as large as the other firm's.

In the first period, a firm may be willing to price below cost because of the advantages that an installed base confers in the second period of price competition, both in terms of improvements in relative product offerings and through any influence on expectations. By

Lemma 1, if firm X wins the first period, then X earns per-capita profits of $V_X(N,0) = \max\{0, \alpha_2 + \gamma_X\}$ in the second period. If firm Y wins the first period, then firm X earns per-capita profits $V_X(0,N) = \max\{0, \alpha_2 + \gamma_Y\}$ in the second period. Let Π_Z denote the per-capita value to firm Z of a larger installed base when competing for second-period sales: $\Pi_Z \equiv V_Z(N,0) - V_Z(0,N)$. These calculations establish that

$$\Pi_X = \max\{0, \alpha_2 + \gamma_X\} - \max\{0, \alpha_2 + \gamma_Y\}.$$

Similar calculations show that

$$\Pi_Y = \max\{0, -(\alpha_2 + \gamma_Y)\} - \max\{0, -(\alpha_2 + \gamma_X)\}.$$

Taking into account the price floors, firm X wins first-period sales if and only if $\max\{d_1 - \Pi_Y, g_1\} - \max\{c_1 - \Pi_X, f_1\} + \kappa \geq 0$. We can now summarize the first-period equilibrium:

Lemma 2. *Suppose that $f_2 \leq c_2$ and $g_2 \leq d_2$. Firm X wins first-period sales if and only if $\max\{d_1 - \Pi_Y, g_1\} - \max\{c_1 - \Pi_X, f_1\} + \kappa \geq 0$. If X wins, it makes sales at $p_1 = \max\{d_1 - \Pi_Y, g_1\} + \kappa$. If Y wins, it makes sales at $q_1 = \max\{c_1 - \Pi_X, f_1\} - \kappa$. Π_X and Π_Y have the following values:*

- *Anticipated X sales: If $\alpha_2 + \gamma_Y > 0$, then $\Pi_X = \gamma_X - \gamma_Y$ and $\Pi_Y = 0$.*
- *Second-period matching: If $\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$, then $\Pi_X = \alpha_2 + \gamma_X$ and $\Pi_Y = -(\alpha_2 + \gamma_Y)$.*
- *Anticipated Y sales: If $0 > \alpha_2 + \gamma_X$, then $\Pi_X = 0$ and $\Pi_Y = \gamma_X - \gamma_Y$.*

This laissez-faire equilibrium may not be efficient. While one tends to think of the incumbent having too much power, the market outcome can be biased toward new firms (*i.e.*, toward firm Y when it has higher costs than firm X in period 1 but lower costs in period 2) when all consumers are optimal coordinators.²¹ With other expectations, the market can exhibit different biases.

²¹ This bias is explored in Katz and Shapiro (1986a).

Are these distortions the result of predation? We observe that a firm that prices below cost in the first period does so in order to gain a second-period advantage, and part of that advantage arises from weakening its second-period rival. At a minimum, the market outcome can exhibit below-cost pricing and ex post monopoly that might be mistaken for predation. We analyze how floors designed to block predation affect market performance, whether or not one describes the laissez-faire outcome as “predatory.”

The following result follows immediately from Lemmas 1 and 2.

Proposition 1. *Suppose that $f_2 \leq c_2$ and $g_2 \leq d_2$. If the price floors do not shift the first-period equilibrium technology choice, then first-period prices weakly increase, and second-period prices and technology choice are unaffected. Gross consumption benefits, total production costs, and hence total surplus are also unaffected. Thus, profits weakly increase while aggregate consumer surplus weakly falls by the same amount.*

Not surprisingly, first-period consumers can be harmed by a price floor because it lowers the surplus that the losing firm can offer first-period consumers, and that surplus can drive the offer made by the winning firm. Second-period consumers are unaffected. Notice that, with the perfectly inelastic market demand of our simple model, price changes do not affect allocative efficiency given that technology choice is unaffected.

The analysis is much more complex when price floors affect the equilibrium choice of technology. We analyze this problem for two leading policy proposals from the literature.

IV. AREEDA-TURNER COST-BASED FLOORS

One rule, associated with Areeda and Turner (1975), is to dub a price predatory if and only if it is below cost. In practice, the appropriate meaning of “cost” may be problematic. Should one use long-run marginal cost, short-run marginal cost, average variable cost, average

total cost, or something else?²² Fortunately, in our simple model all these cost concepts coincide. The Areeda-Turner rule (“A-T rule”) corresponds to $f_t = c_t$ and $g_t = d_t$. The issue is whether prohibiting restricting below-cost pricing improves welfare.

Both courts and Areeda and Turner (1975) recognize that there may be legitimate business reasons for pricing below cost, but have not made clear how one tells “good” below-cost pricing from “bad.”²³ We will examine the effects of a policy that simply prohibits below-cost pricing without distinction. This analysis sheds light both on the potential benefits and risks of policy intervention and on the difficulty of drawing such distinctions.

A. Symmetric Application of Cost Floors

With cost-based floors in effect, firm X wins the first period if and only if $\alpha_1 + \kappa \geq 0$. Absent the floors, X wins the first period if and only if $\alpha_1 + \kappa + \Pi_X - \Pi_X \geq 0$. It is useful to consider separately various cases that give rise to different values of Π_X and Π_Y .

Anticipated X Sales ($\alpha_2 + \gamma_Y > 0$). Firm Y is unwilling to price below cost in the first period because it will make no second-period sales in any event. Anticipated X sales imply $\kappa \geq 0$. By assumption, $\alpha_1 \geq 0$. Hence, $\alpha_1 + \kappa \geq 0$ and, by Lemma 2, firm X can win first-period sales without having to price below cost. Therefore, the price floors have no effect on the equilibrium outcome.

Anticipated Y Sales ($0 > \alpha_2 + \gamma_X$). In this case, firm X is unwilling to price below cost in the first period, but firm Y is willing to go as much as $\Pi_Y = \gamma_X - \gamma_Y \geq 0$ below cost. Thus, enforcement of a price floor can meaningfully constrain firm Y . The possible outcomes are:

²² For a survey of these issues, see Ordoover and Saloner (1989).

²³ In *Brooke Group Ltd. v. Brown & Williamson Tobacco Corp.*, 509 U. S. 209 (1993), the Supreme Court declared that a necessary but not sufficient condition for pricing to be predatory is that it be below cost.

- For $\alpha_1 + \kappa - \Pi_Y > 0$, firm X makes first-period sales in either regime, but with the price floor it does so at a weakly higher first-period price: $d_1 + \kappa$ rather than $d_1 + \kappa - \Pi_Y$.
- For $0 > \alpha_1 + \kappa$, firm Y wins first-period sales under either regime at a price above its costs, and the pricing floor does not affect the equilibrium outcome.
- For $\alpha_1 + \kappa > 0 > \alpha_1 + \kappa - \Pi_Y$, the price floor shifts the first-period winner from Y to X . Firm X makes sales at a price of $d_1 + \kappa$ with the pricing floor, whereas firm Y makes sales at a price of $c_1 - \kappa$ without it. Thus, the price floor changes the first-period equilibrium price by $\alpha_1 + 2\kappa$, which may be positive or negative. Because the floor shifts the first-period technology from Y to X , it lowers network benefits per consumer by β , so its net effect on a first-period consumer's surplus is $-\alpha_1 - 2\kappa - \beta$. For any $\kappa \geq -\beta$, this effect is less than or equal to $-(\alpha_1 + \kappa) < 0$.²⁴ For other expectations processes, however, first-period consumer surplus may rise.²⁵ Turning to the second period, the price falls from $c_2 - \gamma_Y$ to $c_2 - \gamma_X$, but second-period consumers' network benefits fall by β per unit. Hence, the net effect on each second-period consumer's surplus is $\gamma_X - \gamma_Y - \beta$, which can be positive or negative.

Per-capita, network benefits fall by β and production costs fall by $\alpha_1/2$. Because firm Y will make second-period sales anyway, the second best entails firm X 's winning in the first period if and only if $\alpha_1 - 2\beta \geq 0$. Therefore, when $\kappa > -2\beta$, the A-T outcome is biased toward X , the firm with the first-period cost advantage. X wins first-period sales under the unconstrained market outcome if and only if $\alpha_1 + \kappa - \Pi_Y = \alpha_1 + \kappa - \gamma_X + \gamma_Y \geq$

²⁴ With first-period optimal coordinators, $\kappa = -\beta$, while first-period stubborn expectations for X yield $\kappa = 0$.

0. With optimal coordinators in both periods, $\kappa - \gamma_X + \gamma_Y = -3\beta$, and firm X wins if and only if $\alpha_1 - 3\beta \geq 0$; the laissez faire outcome is biased toward the firm with the second-period cost advantage. Thus, the policy choice is between offsetting biases.

Second-period Matching ($\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$). Whichever firm makes first-period sales will also make second-period sales, so gross consumption benefits are $v(2N)$ per-capita in any case. Hence, the effects on consumer surplus and total surplus derive solely from changes in prices and production costs, respectively. Absent price floors, both firms are willing to price below cost to win first-period sales, $\Pi_X > 0$, $\Pi_Y > 0$, and firm X wins if and only if $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y \geq 0$. Recall that the total surplus maximizing rule is that firm X wins if and only if $\alpha_1 + \alpha_2 \geq 0$. Hence, the unconstrained market outcome's bias toward firm X has the sign of $\kappa + \alpha_2 + \gamma_X + \gamma_Y$. With A-T price floors, X wins both periods if and only if $\alpha_1 + \kappa \geq 0$ and the bias toward firm X has the sign of $\kappa - \alpha_2$. When first- and second-period consumers are optimal coordinators, $\kappa = 0 = \gamma_X + \gamma_Y$: the unconstrained market is biased toward firm Y , while A-T is biased toward firm X (if $\alpha_2 > 0$, firm X wins in either case).

Turning to specific cases and allowing for other expectations processes:

- If $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y > 0$ and $\alpha_1 + \kappa > 0$, then firm X wins first-period sales under either regime. The sole effect of the price floor is to raise the first-period price by Π_Y . Thus, firm X is more profitable and first-period consumers are worse off.
- If $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y < 0$ and $\alpha_1 + \kappa < 0$, then firm Y wins first-period sales under either regime. The sole effect of the price floor is to raise the first-period price by Π_X .

²⁵ For example, with stubborn expectations for Y , $\kappa = -(\delta + \beta)$ and the net effect of the price floor on a first-period consumer's surplus is $-\alpha_1 + 2\delta + \beta = -(\alpha_1 + \kappa) + \delta$, which can be positive or negative.

- If $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y > 0$ and $\alpha_1 + \kappa < 0$, then firm X wins first-period sales under laissez faire and Y wins under A-T.²⁶ The change in the first-period winning price is $(c_1 - \kappa) - (d_1 + \kappa + \alpha_2 + \gamma_Y) = -(\alpha_1 + \kappa) - (\alpha_2 + \gamma_Y) - \kappa$. All three terms in the rightmost expression are positive. When firm X has won the first period, it wins the second period at $p_2 = d_2 + \gamma_X$, with or without the price floors. Likewise, when firm Y has won the first period, it wins the second period at $q_2 = c_2 - \gamma_Y$, with or without the price floors. Hence, second-period price changes by $-(\alpha_2 + \gamma_X + \gamma_Y)$ when the first-period winner shifts from X to Y . For second-period optimal coordinators or lagged expectations, $\gamma_X + \gamma_Y = 0$.²⁷ Hence, $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y > 0$ and $\alpha_1 + \kappa < 0$ imply that $\alpha_2 > 0$ and the second-period price falls. However, if second-period consumers have stubborn expectations for Y , then $\gamma_X = 0$ and the second-period price rises because second-matching implies that $\alpha_2 + \gamma_Y < 0$. The change in per-capita total surplus equals minus the change in costs, or $-(\alpha_1 + \alpha_2)/2$, which can be positive or negative.
- If $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y < 0$ and $\alpha_1 + \kappa > 0$, then firm Y wins first-period sales under laissez faire and X wins with A-T floors in effect. The change in the first-period winning price is $(d_1 + \kappa) - (c_1 - \kappa - \alpha_2 - \gamma_X) = (\alpha_1 + \kappa) + (\alpha_2 + \gamma_X) + \kappa > \kappa$. With first-period optimal coordinators, $\kappa = 0$, and the first-period price rises. However, when first-period expectations stubbornly favor Y , $\kappa = -(\delta + \beta)$ and the first-period price falls for some parameter values. The change in the second-period winning price is $\alpha_2 + \gamma_X + \gamma_Y$. For second-period optimal coordinators or lagged expectations, $\gamma_X + \gamma_Y = 0$. Hence, $\alpha_1 + \kappa +$

²⁶ $\kappa = 0$ when first-period consumers are optimal coordinators, and this case does not arise.

²⁷ When second-period expectations track prices, $\gamma_X + \gamma_Y = 0$ but second-period matching cannot arise.

$2\alpha_2 + \gamma_X + \gamma_Y < 0$ and $\alpha_1 + \kappa > 0$ imply that $\alpha_2 < 0$ and the second-period price falls. If second-period consumers have stubborn expectations for X , then $\gamma_Y = 0$ and the second-period price rises because second-period matching implies $\alpha_2 + \gamma_X > 0$. Lastly, the change in total surplus equals minus the change in costs, or $(\alpha_1 + \alpha_2)/2$, which can be positive or negative even when both cohorts are optimal coordinators. Notice that in some cases prices in both periods can fall due to the floors. The first-period price can fall because the floor shifts the winner to the firm that faces unfavorable expectations and thus must price well below the price set by its rival. Second-period prices may fall because the first-period floors shift the identity of the second-period loser to the firm that can offer greater surplus as a loser, which is what drives equilibrium pricing.

Summarizing these many cases, we have:

Proposition 2. *Areeda-Turner price floors may or may not shift the identity of the firm making equilibrium sales in a period. When first-period consumers are optimal coordinators, the floors: shrink the set of parameter values for which the firm with higher initial costs makes equilibrium sales; lower or leave unchanged first-consumer surplus; and raise or leave unchanged the surplus of second-period optimal coordinators. In other cases, the floors may: expand the set of parameter values for which the firm with higher initial costs makes equilibrium sales; increase first-period consumer surplus; or lower second-period consumer surplus. When the floors shift the equilibrium technology choice, total surplus rises in some cases and falls in others, even when both cohorts are rational coordinators.*²⁸

²⁸

The model can readily be extended to allow for one technology to be unsponsored (*i.e.*, produced by a set of competitive firms all sharing the same technology). Unsponsored technologies don't price below cost in any event. Thus, banning below-cost pricing favors unsponsored technologies. The market biases due to sponsorship are explored in Katz and Shapiro (1986a).

B. Asymmetric Application of Cost Floors

Some commentators have recommended that rules against predation be applied only to dominant firms.²⁹ One strategy for modeling dominance is to introduce a production period prior to period one in which only firm X is active. In the Appendix, we show that, when the network benefit function, $v(\cdot)$, is affine, one can think of firm X 's cost advantages (α_1 and α_2) as reduced forms reflecting an installed base firm X has at the start of the first period of competition with firm Y . In this interpretation, firm Y can be viewed as an *entrant* and firm X as the *incumbent*. When $v(\cdot)$ is not affine over the relevant range, there is no exact isomorphism between the two-period and three-period models, but the model may still be a useful approximation.

By Proposition 2, symmetric application of the A-T rule may help the incumbent and harm the entrant. Suppose firm X is declared dominant because $\alpha_1 \geq 0$, independently of consumers' expectations processes. As always, the analysis is broken down into cases.

Anticipated X Sales ($\alpha_2 + \gamma_Y > 0$). In this case, the floor does not affect the outcome. Firm Y is unwilling to price below cost in the first period, and firm X can thus win first-period sales without pricing below cost—it has lower first-period costs than firm Y and consumer expectations favor firm X as well.

Anticipated Y Sales ($0 > \alpha_2 + \gamma_X$). In this case, firm X is unwilling to price below cost in the first period, so the floor again makes no difference.

Second-period Matching ($\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$). Absent price floors, X wins if and only if $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y \geq 0$. With the asymmetric price floor, X wins first-period sales if and only if $\alpha_1 + \kappa + \alpha_2 + \gamma_Y \geq 0$. Using the fact that $\alpha_2 + \gamma_X > 0$, one gets the expected result that

²⁹ See, for example, Joskow and Klevorick (1979).

the asymmetric floor shrinks the set of parameter values for which X wins. Recall that the total surplus maximizing rule is that firm X wins if and only if $\alpha_1 + \alpha_2 \geq 0$. If $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y > 0 > \alpha_1 + \kappa + \alpha_2 + \gamma_Y$, then the rule strictly reduces welfare when $\alpha_1 + \alpha_2 > 0$, and strictly increases welfare when $\alpha_1 + \alpha_2 < 0$. In other cases it has no effect.

When first- and second-period consumers are optimal coordinators, $\kappa = 0$ and $\gamma_X = \beta = -\gamma_Y$. If $\alpha_1 + 2\alpha_2 > 0 > \alpha_1 + \alpha_2 - \beta$ then the rule strictly reduces welfare when $\alpha_2 > 0$, and strictly increases welfare when $\alpha_1 + \alpha_2 < 0$. The asymmetric floor can harm welfare because the market may be biased in favor of the entrant and the use of below-cost pricing by firm X to keep firm Y from making sales may be efficient.

When first-period consumers stubbornly favor X and second period consumers are optimal coordinators, $\kappa = \beta$ and $\gamma_X = \beta = -\gamma_Y$. If $\alpha_1 + 2\alpha_2 + \beta > 0 > \alpha_1 + \alpha_2 - \beta$ then the rule strictly reduces welfare when $\alpha_2 > 0$, and strictly increases welfare when $\alpha_1 + \alpha_2 < 0$.

When first- and second-period consumers stubbornly favor X , $\kappa = \delta + \beta = \gamma_X$ and $\gamma_Y = 0$. Now, if $\alpha_1 + 2\alpha_2 + 2(\delta + \beta) > 0 > \alpha_1 + \alpha_2 + \delta + \beta$, then the rule strictly increases welfare (it must be the case that $\alpha_1 + \alpha_2 < 0$). In other cases, the rule has no effect when both cohorts stubbornly favor X .

Summarizing this analysis.

Proposition 3. *When first- and second-period expectations stubbornly favor firm X , application of an Areeda-Turner cost-based price floor solely to firm X weakly increases total surplus. In other cases, including first- and second-period optimal coordination, asymmetric application of an Areeda-Turner floor can strictly raise, strictly lower, or leave unchanged total surplus.*

This result suggests that application of an A-T floor solely to dominant firms could improve welfare, but only if consumers' expectations stubbornly favor incumbents (which is an

open question) or if the definition of dominance were tied to the underlying consumer expectations process (which may be difficult in practice).

V. THE ORDOVER-WILLIG COUNTERFACTUAL

It should come as no surprise to find that marginal-cost price floors—which are motivated by static models of profit-maximization—should have problems in a dynamic context, such as markets subject to network effects. Ordover and Willig (1981) propose a test that aims to take the dynamics of competition into account: “predatory objectives are present if a practice would be unprofitable without the exit it causes, but profitable with the exit.”³⁰ To apply this test, one must construct a counterfactual in which both firms remain in the market despite one firm’s taking an action that in fact drives its rival to exit.

A. Ordover-Willig in the Baseline Model

Because denying a rival sales weakens its ability to compete even if it does not shut down entirely, we believe Ordover and Willig’s narrow focus on exit is inappropriate in markets with increasing returns to scale.³¹ Instead, their definition of predation should be modified to mean that, in setting its first-period price, a firm cannot take into account the benefits of reducing its rival’s network. In our model, that means assuming that, if a firm wins first-period sales, its second-period payoff will be *as if* its rival also had sales of N in the first period. This generates price floors by affecting the notional value of γ_Z and hence (in many cases) reducing Π_Z .

Unlike the Areeda-Turner floors, these modified Ordover-Willig (“modified O-W”) price floors depend on more than current-period costs. Consider how low firm X may price in the first

³⁰ Ordover and Willig (1981) at 9.

³¹ Moreover, in our model, a firm with no sales still constrains its rival’s pricing, and predation defined in terms of exit would be impossible.

period. The rule requires that prices be rational under a counterfactual that reflects self-strengthening but not rival-weakening. If X wins first-period sales, then in the notional second-stage game the installed bases will be N for each firm. If firm Y wins the first period, then *from X 's perspective*, the notional second-stage installed bases will be 0 and N , reflecting the idea that X may take into account improvement in its own product but not the weakening of its rival's.

With second-period optimal coordinators, firm X would earn notional profits of $\max\{\alpha_2, 0\}$ per unit in the second period if it won the first. Firm X would earn profits of $\max\{\alpha_2 - \beta, 0\}$ if Y won the first period. Hence, firm X is allowed to go as low as $\max\{\alpha_2, 0\} - \max\{\alpha_2 - \beta, 0\}$ below cost in the first period. Similar calculations for firm Y establish that it is allowed to go as low as $\max\{-\alpha_2, 0\} - \max\{-\alpha_2 - \beta, 0\}$ below cost in the first period.

With stubborn expectations for X in the second period, firm X would earn notional profits of $\max\{\alpha_2 + \beta, 0\}$ per unit in the second period if it won the first. It would earn profits of $\max\{\alpha_2, 0\}$ if Y won the first period. Hence, firm X is allowed to go as low as $\max\{\alpha_2 + \beta, 0\} - \max\{\alpha_2, 0\}$ below cost in the first-period. This is not the same floor as for optimal coordinators: to see this, consider $\alpha_2 = 0$, which yields a floor β below cost here, but at cost with optimal coordinators. One could do similar calculations for the case in which Firm Y wins and for stubborn expectations that favor Y .

As these calculations illustrate, the modified O-W floors are sensitive to the expectations formation process, so that implementation would require investigation of both actual and counterfactual expectations. Moreover, when second-period consumers have lagged expectations, consumer behavior in the notional outcome is not well defined: What do second-period consumers expect in the notional event that *both* firms come into the second period with installed bases of N ? Notwithstanding these obstacles to practical implementation of this policy,

we examine the rule's consequences for equilibrium in our model under the assumption that second-period consumers are optimal coordinators.

Second-period Matching. If $0 < \alpha_2 < \beta$, then firm X is subject to a first-period price floor of $c_1 - \alpha_2$, while firm Y is subject to a floor of d_1 . If $0 < -\alpha_2 < \beta$, firm X is subject to a first-period floor of c_1 , while firm Y is subject to a floor of $d_1 + \alpha_2$. In either case, firm X wins in both periods if and only if $\alpha_1 + \alpha_2 + \kappa \geq 0$.

Recall that, in the absence of intervention, when $|\alpha_2| < \beta$, firm X wins in both periods if $\alpha_1 + 2\alpha_2 + \kappa \geq 0$ and Y wins otherwise. The welfare-maximizing selection rule is, however, $\alpha_1 + \alpha_2 \geq 0$. The laissez-faire and modified O-W outcomes can each be biased in a different way. When consumers are optimal coordinators, $\kappa = 0$ and the modified O-W rule leads to the first best. Hence, it weakly improves welfare. In other cases, the modified O-W rule can reduce welfare. Suppose, for example, that $\kappa = -\alpha_2$. Then the unconstrained outcome is efficient, while the modified O-W rule is biased if $\alpha_2 \neq 0$.

Anticipated X Sales. When $\alpha_2 > \beta$, firm X always makes second-period sales, it is efficient for it to win both periods, and $\kappa \geq 0$. Under the modified O-W rule, firm X faces a first-period price floor of $c_1 - \beta$, firm Y faces a floor of d_1 , and X wins the first period if and only if $\alpha_1 + \kappa + \beta \geq 0$. Absent intervention, X wins the first period if and only if $\alpha_1 + \kappa + \alpha_2 + \beta \geq 0$. Because $\kappa > -\alpha_1 - \beta$, firm X wins both periods with or without price floors.

Anticipated Y Sales. Lastly, consider the case in which $-\alpha_2 > \beta$. In this case, firm Y always makes second-period sales. Under the O-W rule, firm X faces a first-period price floor of c_1 , firm Y faces a floor of $d_1 - \beta$, and firm X wins the first period if and only if $\alpha_1 + \kappa - \beta \geq 0$. In the absence of intervention, firm X wins the first period if and only if $\alpha_1 + \kappa - 2\beta \geq 0$. Given

that firm Y will make second-period sales no matter what, the second best entails firm X 's winning the first period if and only if $\alpha_1 - 2\beta \geq 0$. Thus, the modified O-W rule leads to the second-best when $\kappa = -\beta$, as arises when first-period consumers are optimal coordinators, and can strictly improve welfare. On the other hand, if $\kappa = 0$, the market outcome is second-best optimal absent intervention and application of O-W can distort the outcome.

Summarizing lo these many cases:

Proposition 4. *When consumers in both periods are optimal coordinators, application of the modified Ordover-Willig rule weakly improves the equilibrium technology choices and resulting total surplus, and may do so strictly. For other first-period consumer expectation processes, the modified Ordover-Willig rule may strictly increase, strictly decrease, or leave unchanged total surplus.*

B. Ordover-Willig in a Model with Exit

In the model above, firms compete in the first period for a second-period advantage that will enable them profitably to take 100 percent of the second-period market. But we assumed that the loser lurks on the fringe of the second period and continues to constrain the winner's price. One might object that this model does not capture what has been the main focus of legal concerns about predation, namely that the loser *exits* and the first-period winner thus acquires not just a dominant position but a strict *monopoly*.³²

Accordingly, we now modify our model to allow exit between periods, and re-evaluate the competition that ensues. After first-period product market competition is completed and all participants observe the results, each firm must choose whether to pay a fixed cost of $R > 0$ to

³² The word "monopoly" needs to be used with caution, especially in markets where undifferentiated Bertrand competition prevails; we use it here to mean that the winner's price is not constrained by competitors' offers, but only by consumers' willingness to pay.

remain in the market. R might represent the R&D cost of remaining current. It could equally be any “fixed cost” of having a product offering (not a cost that is avoided by having zero sales). If no firm pays R , there are no second-period sales and each firm earns 0 in the second period. If just one does so, it has a second-period monopoly. If both firms pay R , they compete in the second period in the way explored above. Firms and consumers observe who has paid R before second-period price and purchase decisions are made.

As just noted, the gross continuation payoffs after both firms remain in the market have been analyzed above. One firm will lose the second period and thus get zero profits gross of R ; the other firm will win and get a (generically strictly) positive continuation payoff gross of R . On the other hand, if just one firm pays R , it gets a second-period monopoly gross payoff. If, for instance, firm X wins the first period and pays R , while Y drops out, then X can charge $v(2N)$ in the second period. If firm X wins the first period but then drops out, and Y pays R , then Y can charge $v(N)$ in the second period.

If second-period monopoly profits exceed R but duopoly profits (even for the winner) are below R , then the subgame always has two pure-strategy equilibria: In one, X stays in and Y exits, while in the other, Y stays in and X exits. For brevity, we focus on cases in which equilibrium is unique. Such uniqueness may happen in two ways. First, exit might be a dominant strategy for one (“weak”) firm: even its monopoly second-period payoff would not cover R . Second, paying R might be a dominant strategy for one (“strong”) firm: It would win a second-period duopoly and even its duopoly second-period payoff would cover R .

We examine the latter case and restrict attention to small-but-positive values of R for which the unique continuation equilibrium is for just the firm that would win the second-stage

duopoly to make the investment necessary to serve second-period consumers.³³ Hence, the profits associated with winning the second period are its monopoly profits minus R , but the selection rule for winning the second period is the same as in our earlier model.

Lemma 3. *When a small-but-positive investment is needed to continue, firm X wins second-period sales if and only if $\alpha_2 + \gamma_Z \geq 0$, where Z is the firm that made first-period sales. If X wins the second period, it does so at the monopoly price of $p_2 = v(S+N)$, where S is firm X 's first-period sales. If Y wins the second period, it does so at the monopoly price of $p_2 = v(2N-S)$.*

In the first period, each firm is willing to price below cost if doing so allows it to become the second-period monopolist or increases the profits it will earn as a monopolist. There will always be a second-period monopoly in this model.

Lemma 4: *When a small-but-positive investment is needed to continue, firm X wins first-period sales if and only if $\alpha_1 + \Pi_X - \Pi_Y + \kappa \geq 0$. If X wins, it makes sales at $p_1 = d_1 - \Pi_Y + \kappa$. If Y wins, it makes sales at $q_1 = c_1 - \Pi_X - \kappa$. Π_X and Π_Y have the following values:*

- *Anticipated X sales: If $\alpha_2 + \gamma_Y > 0$, then $\Pi_X = \beta$ and $\Pi_Y = 0$.*
- *Second-period matching: If $\alpha_2 + \gamma_X > 0 > \alpha_2 + \gamma_Y$, then $\Pi_X = v(2N) - c_2$ and $\Pi_Y = v(2N) - d_2$.*
- *Anticipated Y sales: If $0 > \alpha_2 + \gamma_X$, then $\Pi_X = 0$, and $\Pi_Y = \beta$.*

The (un-modified) O-W rule requires a firm setting first-period prices to ignore the fact that, if it wins first-period sales, its rival will exit. Here, this means that firms must be able to justify their first-period prices as if they were playing our baseline model, in which exit does not occur (but with no additional price floors). Thus, the O-W rule may allow a firm to price below cost in the first period, and it even allows it to take into account weakened rival effects. The rule

³³ As before, we assume that all second-period consumers purchase the good in equilibrium. A sufficient condition for this property to be satisfied by any fulfilled expectations equilibrium is that $v(S) > \max\{c_2, d_2\}$, where S is the monopolist's first-period sales level.

does not, however, allow a firm to take into account the full benefits of inducing its rival's exit. In the present model, the O-W rule never entails a floor above unit costs. Hence, it is weakly more permissive than the A-T rule.

We first note that, when second-period expectations track prices, neither firm would price below cost in our baseline model (there is no second-period advantage gained by winning the first period because second-period consumers simply compare prices). Hence, when second-period expectations track prices, the O-W rule is equivalent to A-T floors.

In the case of anticipated X sales, the O-W rule would allow firm X to price as much as $\gamma_X - \gamma_Y$ below cost in the first period (see Lemma 2 above), but X is not willing to price more than β below cost. Hence, if $\gamma_X - \gamma_Y \geq \beta$, the O-W rule has no effect in the case of anticipated X —or, for similar reasons— Y sales. We note that all three illustrative expectations processes other than tracking prices satisfy this condition.

The O-W floors have no bite in these cases because the change in duopoly profits from winning the first period in the O-W counterfactual is least as large as the change in monopoly profits. O-W allows a firm to price below cost by an amount equal to the difference in duopoly profits due to improving its installed base and reducing its rival's base. Absent intervention, the firm recognizes that it will have a monopoly anyway and is willing to price below cost only to improve its own product, not weaken its rival.

Under second-period matching, firm X is allowed to price $\Pi_X = \alpha_2 + \gamma_X$ below cost and firm Y is allowed to price $\Pi_Y = -(\alpha_2 + \gamma_Y)$ below cost (see Lemma 2 again). Each firm would be willing to go as much as its second-period monopoly profits below cost to win first-period sales, and thus the O-W floors do constrain pricing. Firm X wins first-period sales if and only if $\alpha_1 + \kappa + \Pi_X - \Pi_Y \geq 0$, which is equivalent to $\alpha_1 + \kappa + 2\alpha_2 + \gamma_X + \gamma_Y \geq 0$. In the unconstrained outcome,

firm X wins if and only if $\alpha_1 + \kappa + \alpha_2 \geq 0$. Recall that the total surplus maximizing rule is that firm X wins if and only if $\alpha_1 + \alpha_2 \geq 0$. When first-period consumers are optimal coordinators, $\kappa = 0$ and the unconstrained market outcome is optimal.³⁴ Thus, the O-W rule weakly lowers welfare in this case. When second-period consumers are optimal coordinators also, $\gamma_X + \gamma_Y = 0$ and the O-W rule can strictly lower welfare through its bias in favor of the entrant.

Proposition 5. *Suppose a small-but-positive investment is needed for a firm to continue in the second period. When second-period expectations track prices, the Ordo-over-Willig rule imposes Areeda-Turner cost floors. When first-period consumers are optimal coordinators and second-period expectations satisfy $\gamma_X - \gamma_Y \geq \beta$, the Ordo-over-Willig rule either lowers total surplus or leaves it unchanged. This condition is satisfied if second-period consumers are optimal coordinators, stubbornly favor one firm, or track prices. The Ordo-over-Willig rule may strictly raise total surplus in other cases.*

We considered the model with exit in part because it seems closer to the situation that the O-W rule is meant to address. We find that the rule fails in theory, and not just practice. While the rule is designed to prevent monopoly from being inefficiently created, the rule also acts as a monopoly selection rule in those cases (on which this model focuses) where monopoly is inevitable. The analysis above establishes that it is not a particularly good selection rule.

VI. OTHER DIMENSIONS OF CONDUCT

The imposition of floors designed to prevent predatory pricing may also affect other dimensions of firm conduct. In this section, we briefly consider two.

³⁴ This striking optimality result relies on several assumptions. One, that first-period consumers are optimal coordinators. Two, that bids are in the same order as social surplus, which might otherwise fail to hold if firms had different discount rates or due to cross-firm differences in the fraction of total benefits appropriated when possessing a second-period monopoly (*e.g.*, different abilities to engage in discrimination, different product qualities). Lastly, when the *difference* in the second-period monopoly

A. Compatibility

Although product compatibility leads to the first best in our simple model, one or both of the two firms may favor incompatibility.³⁵ Because the firms may disagree on the desirability of compatibility, the outcome depends on who chooses and on whether side payments between producers are feasible. When compatibility entails making two proprietary interfaces work together, either firm may be able to unilaterally veto compatibility. In other cases, the availability of adapters and the absence of intellectual property rights may enable either firm unilaterally to impose compatibility. If side payments between the firms are possible, compatibility is driven by the change in joint profits.

Proposition 6. *If either: (a) side payments are feasible, or (b) either firm can veto compatibility and side payments are infeasible, then there exist cases in which the firms would choose compatibility in the absence of price floors, but incompatibility when Areeda-Turner cost-based floors are in effect.*

Proof: The proof is by example. Suppose that both cohorts are optimal coordinators, $\alpha_1 = \beta$, and $\alpha_2 = -\beta/2$. Under compatibility, firm X makes first-period sales and earns α_1 , firm Y makes second-period sales and earns $-\alpha_2$, and industry profits are $\pi^c = 3\beta/2$. Under incompatibility with no price floor, firm X wins both periods and earns profits $\pi^i = \alpha_1 + 2\alpha_2 = 0$. Firm Y earns no profits. Lastly, under incompatibility with the price floor in effect, firm X wins both periods and earns $\pi^f = \alpha_1 + \alpha_2 + \beta = 5\beta/2$. By these calculations, $\pi^i < \pi^c < \pi^f$. Hence, the firms jointly choose compatibility absent the price floor, but incompatibility with the price floor.

profits is less than the *difference* in second-period total surplus levels, bidding may lead to the wrong winner even though the orderings of monopoly profits and welfare are the same.

³⁵ See Katz and Shapiro (1986b).

Each firm earns greater profits under compatibility than under incompatibility without a price floor. Thus, both will favor compatibility. In the presence of the price floor, firm X will veto compatibility. **QED**

The intuition underlying this result extends to other price floors as well. A reason for firms to favor compatibility is to soften first-period competition. The “cost” of compatibility is that it can strengthen second-period competition by preventing either firm from building up an installed base advantage over the other. The imposition of a price floor is a substitute mechanism for softening first-period competition. Hence, in the presence of the price floor, compatibility may have private costs but no private benefits.

B. Research and Development

Like compatibility, R&D decisions may be distorted by the presence of price floors. Specifically, the imposition of cost-based price floors can create excessive incentives to conduct cost-reducing R&D—a firm may undertake R&D to relax the price floor on its prices even if the cost of the R&D exceeds the production cost savings.

VII. CONCLUSION

Much of the literature on predation focuses on a doubly special case. First, it is special because it assumes that weakening the rival consists of inducing it to exit and then face insurmountable re-entry barriers. Second, in a model of exit-inducing predation, one must ask why the prey would forego future opportunities merely because of past disappointments. Much of the literature gives a special answer to this question: informational imperfections, often in capital markets.³⁶

³⁶ For a recent survey, see Brodley *et al.* (2000).

Our model suggests a broader scope for predation policy. It observes that, when proprietary network effects create intertemporal increasing returns at the firm level, a rival-weakening (“predatory”) motive for seemingly competitive behavior arises even when information is perfect and complete and when full-blown exit is not at issue.³⁷ Moreover, even if we focus on exit, the intertemporal linkages of costs or demands at the firm level create a cost of exit and re-entry. Our analysis confirms that intertemporal increasing returns such as network effects can lead to predation, even in our setting which is highly favorable for laissez faire (e.g., perfectly inelastic demand so there are no welfare losses due to pricing above marginal costs).

But our model also suggests that successful intervention to address this problem may be exceptionally difficult. Simple cost-based floors (our stylized version of Areeda and Turner) ignore the fundamental intertemporal complementarities that drive both competitive and predatory behavior in our model. Taking these complementarities into account, our model finds that equilibrium, and hence the effects of policy, depend sensitively on how consumers (and, more broadly, complementors) form expectations. While equilibrium expectations might well be observable, one would also need in general to know how expectations would be formed following out-of-equilibrium competitive behavior.

More broadly, it seems almost inevitable that predation policy in network markets will sometimes be fighting the wrong war. We take it that predation policy is meant to prevent the inefficient emergence of monopoly; in other words, when relatively traditional competition in the market is efficiently sustainable, predation policy aims to sustain it. But the same network effects that may make predation possible can also, if strong enough (as in our model), make ex

³⁷ Cabral and Riordan (1997) also discuss the need for *intertemporal economies of scope* to facilitate predatory behavior. In a related vein, Carlton and Waldman (1999) stress the role of intertemporal economies of scale for the practice of tying to deter entry.

post dominance or monopoly inevitable. If so, the main question for economic efficiency may well be (and in our model is) getting the right monopolist. Under laissez-faire, firms compete "for the market" in Schumpeterian fashion. As we saw, this competition may or may not be fully efficient, and it is perfectly possible that policy might make it more efficient. But, our analysis shows, policies designed for the task of stopping the creation of monopoly need not perform well at fine-tuning such us-or-them battles for the market. The Ordovery-Willig rule in particular is often praised as being theoretically correct but criticized as being hard to apply in practice.³⁸ Our analysis shows that, if applied to industries in which monopoly is inevitable, the rule can reduce welfare even if applied by a court with complete information and perfect ability to calculate the relevant counterfactuals.³⁹ Because it is hard to diagnose which industries have which kind of competition, policies cannot readily be applied only to the one kind of competition or the other.

We close by noting two directions in which it would be useful to extend this research. One is to consider asymmetric models of predation and exit. The efficiency of the laissez-faire outcome in the second-period matching case of our model with exit hinged crucially on the fact that *both* firms were bidding symmetrically for second-period monopoly revenues $v(2N)$. If one ("incumbent") firm would stay in the market come what may (perhaps because of closely related operations in other markets, or better financing to pursue options for a third competitive period), while the other firm would exit if it lost the first period, then the welfare economics of first-period bidding for the market would be very different. Under laissez-faire, the incumbent would

³⁸ See for instance Brodley et al. (2000) footnote 208.

³⁹ Although we did not do it here, one could attempt to derive optimal price floors in the context of our model. It is evident that such floors would have to be sensitive to the expectations process. And the robustness of optimality for other models of market equilibrium would be questionable.

be bidding for monopoly, while the entrant would be bidding for a strong duopoly position, which can bias the outcome.⁴⁰

A second interesting extension would be to examine exclusionary behavior in a network model. Exclusionary behavior entails denying rivals access to some resource (*e.g.*, distribution outlets or network interconnection) in order to raise their costs and weaken their ability to compete. Although it is similar to predation in some respects, there are also differences. Two are that predation entails “bidding” for monopoly, which leads to first-period consumers’ appropriating many of the benefits and, more important, a firm’s willingness to bid may be positively correlated with social welfare.⁴¹ Intuition suggests that both may be less true of exclusion.

⁴⁰ Gilbert and Newbery (1982) identify biases when the bidding of this sort takes the form of R&D expenditures.

⁴¹ Indeed, in our model (with exit) this bidding works perfectly when consumers in each cohort are optimal coordinators—bidding to be the second-period monopolist leads to an efficient outcome. Of course, allowing for elastic demand and other consumer expectations would lead to less favorable results.

APPENDIX: ANOTHER INTERPRETATION OF THE MODEL

Let N_0 denote firm X 's installed base at the start of period 1. Moreover, suppose that $v(z) = \nu z$, ν a positive constant. Recall that x_1 and y_1 denote first-period sales and consider the second period. Each firm is willing to price down to cost if necessary in order to win second-period sales. Hence firm X will make sales in the second period if and only if $\gamma(N_0 + x_1 + N) - c_2 > \nu(y_1 + N) - d_2$. This condition is equivalent to $\nu x_1 - (c_2 - \gamma N_0) > \nu y - d_2$. Define $\alpha_2' \equiv d_2 - (c_2 - \nu N_0)$. If X wins the second-period sales, its profits are $\alpha_2' + \nu(x_1 - y_1)$. If Y wins, its profits are $\alpha_2' + \nu(y_1 - x_1)$.

Suppose $\beta > |\alpha_2'|$. Whichever firm wins the first period will win the second. First-period consumers thus make their choice by comparing $p_1 - \nu N_0$ with q_1 . Firm X is willing to go as low as $c_1 - \beta - \alpha_2'$ to win first-period sales, while firm Y is willing to go as low as $d_1 - \beta + \alpha_2'$. Hence, firm X will win if and only if $\alpha_1' + 2\alpha_2' \geq 0$, where $\alpha_1' \equiv d_1 - (c_1 - \nu N_0)$. However, the condition for welfare maximization is that firm X win if and only if $\alpha_1' + \alpha_2' \geq 0$. Comparison with the analysis for $N_0 = 0$ shows it is exactly parallel. One can make a similar showing for the two subcases in which $\beta < |\alpha_2'|$. The analysis clearly generalizes to the case in which $v(\cdot)$ is affine but not linear.

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