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ABSTRACT

We analyze entry, pricing and product design in a model with differentiated products. Under plausible conditions, entry into an initially monopolized market leads to higher prices for some, possibly all, consumers. Entry can induce a misallocation of goods to consumers, segment the market in a way that transfers surplus to producers and undermine aggressive pricing by the incumbent. Post entry, firms have strong incentives to modify product designs so as to raise price by strengthening market segmentation. Firms may also forego socially beneficial product improvements in the post-entry equilibrium, because they intensify price competition too much. Multi-product monopoly can lead to better design incentives than the non-cooperative pricing that prevails under competition.

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1 Introduction

This paper studies entry, pricing and product design incentives in a market with differentiated products. In our model, an incumbent monopolist and a potential rival vie for sales to heterogeneous consumers, and the incumbent may either accommodate entry or price to exclude the rival. Successful entry yields complete displacement of the incumbent or, more interestingly, coexistence in a separating equilibrium where consumers choose between rival products based on relative valuations. We show that an incumbent monopolist raises price in response to entry under plausible conditions, and that entry can reduce welfare. Entry can harm consumers by inducing a misallocation of goods to buyers, by segmenting the market in a way that transfers surplus to producers, and by undermining the incumbent's willingness to price aggressively.

In contrast, potential entry is highly beneficial to consumers when it elicits an "exclusionary" pricing response by the incumbent. The incumbent then retains the entire market, but only by pricing low enough to preclude rival sales. Reminiscent of the "contestable markets" paradigm of Baumol, Panzar, and Willig (1982), this exclusionary outcome also fits the situation in which the potential entrant operates in a market "adjacent" to the incumbent's. The key point is that the threat of entry (or expansion) constrains the incumbent's price, even though the incumbent retains its market.

Exclusionary pricing is not always attractive to the incumbent, however; a stronger rival with a better product can compel the incumbent to accommodate entry and retreat to less aggressive pricing behavior. In our model, entry always causes a fall in consumer surplus relative to an exclusionary pricing regime and sometimes relative to a pure monopoly regime with no rival. Entry can reduce total surplus relative to either pre-entry regime. It follows that high market share is a poor indicator of monopoly pricing power, consumer harm, and inefficiency.

We also analyze post-entry product design incentives for the incumbent and its rival. Once an entrant establishes a secure market position, both firms have strong incentives to modify product designs in ways that strengthen market segmentation and weaken price competition, thereby transferring surplus from consumers to producers. A firm can soften price competition by making its product more attractive to its own

customers without making it too much more attractive to its rival's customers. Under some circumstances, a firm willingly degrades product quality in the eyes of all consumers in order to soften price competition. More generally, in an environment with differentiated products, the "direction" of design modifications greatly influences the intensity of price competition. This influence on pricing distorts innovation incentives relative to a consumer surplus or total surplus benchmark.

Adverse design incentives can also arise when a single firm sells both products, but we show that adverse incentives are often weaker under multi-product monopoly than under non-cooperative pricing with two firms. This result reflects an important difference between monopoly and non-cooperative pricing with differentiated products: by coordinating the pricing structure among imperfect substitutes, a multi-product monopolist is better able to extract surplus without resorting to inferior product designs.

Our analysis is most apt for markets with heterogeneous consumers and a few distinct locations in product space. Market segmentation is a natural consequence of entry in this type of environment. Perhaps the best-known example of entry-induced segmentation involves the impact of generic equivalents when a brand name prescription drug goes off patent. Post entry, the branded version typically retains a large market share while selling for a much higher price than its generic equivalents. There is also evidence that generic entry often triggers an increase in the brand price, although empirical studies differ on this issue.[1] On a related front, Perloff, Suslow and Sequin (1996) find mixed price responses to entry by new anti-ulcer prescription drugs. Their evidence suggests that price rises for an incumbent drug in response to entry by a distant therapeutic substitute but falls in response to entry by a closer substitute. This mixed pattern fits our theory, which predicts that the price response of the incumbent depends on relative positions in product space, consumer preferences and the distribution of consumer types.

Other markets also show evidence of entry-induced price increases. For example, Bresnahan and Reiss (1990) infer that variable profit margins rise modestly when a second new car dealership (typically Ford) enters an isolated rural market formerly served by a single dealership (typically General Motors). This finding suggests that a

[1] See, for example, Caves *et al.* (1991), Grabowski and Vernon (1992) and Frank and Salkever (1997). Frank and Salkever provide the most compelling evidence that generic entry triggers higher prices for chemically equivalent brand name prescription drugs.

second dealership leads to greater segmentation in the local retail market and larger markups over wholesale prices. Ward *et al*. (2001) study the impact of private-label entry and market penetration on brand name pricing for 32 food product categories (e.g., baked beans, peanut butter, canned hams and gelatin mixes). Using scanner data on retail prices during the late 1990s, they find a strong *positive* effect of private-label market share on brand name prices in many categories. They also compile anecdotal evidence of brand name price *cuts* in response to private-label entry.

Our analysis speaks to certain issues that arose in connection with *United States v. Microsoft* and the many class-action suits that followed in its wake. The government case drew attention to a pricing puzzle: Reasonable calculations place the static monopoly price of Microsoft Windows at several hundred dollars per copy, but the average price of Windows to computer manufacturers has been only about $60 in recent years (Reddy *et al.,* 1999). No single factor is likely to explain this huge gap between actual and monopoly prices, but our analysis suggests that the presence of IBM's OS/2 during the first half of the 1990s, and Linux more recently, may have played a role – despite small market shares or niche status – by prompting Microsoft to price Windows so as to prevent expansion by rivals.

An important issue in the class-action suits is whether additional entry (or expansion by existing rivals) would have meant lower prices for Microsoft Windows or MS-DOS. Our analysis shows that additional entry could trigger higher prices by segmenting the market. This conclusion holds whether or not exclusionary behavior influenced the actual prices of Windows and MS-DOS. The conclusion is reinforced insofar as entry-induced segmentation would create incentives to further soften price competition by suitable changes in product design.

More generally, our analysis highlights a crucial distinction between the exclusion of rival sales through aggressive pricing or product design and the exclusion of rivals from the competitive process. Aggressive pricing by a leading firm benefits consumers, even when it excludes rivals from all or most of the market. Indeed, exclusionary pricing with high market share by a leading firm can be symptomatic of a highly competitive environment. Likewise, we show that "exclusionary" own-product design changes are

pro-competitive in our model. That is, own-product improvements aimed at the exclusion of rival sales unambiguously benefit consumers.

The paper proceeds as follows. The next section briefly reviews related theoretical work. Section 3 lays out the basic framework of the model and defines the equilibrium concept. Section 4 derives the post-entry pricing equilibrium and shows that it may involve market segmentation with sales by both firms, or exclusionary pricing and sales by a single firm. Section 5 analyzes the relationship between market structure and efficiency, and Section 6 analyzes product design incentives in the post-entry equilibrium. Section 7 draws on the preceding sections to analyze the impact of entry on pricing. Section 8 considers multi-product monopoly and compares it to the duopoly market structure, and Section 9 concludes.

2 Related Theoretical Work

D'Aspremont *et al.* (1979), Shaked and Sutton (1982) and Economides (1986) show that rival firms have strong incentives to produce differentiated products in order to soften price competition. We obtain a similar result under a different demand structure and using a different equilibrium concept. Our characterization of consumer demand and the product space is very simple but also more flexible than earlier work.[2] Tirole (1988, chapter 7) analyzes pricing and product location in a variety of models with product differentiation. He emphasizes pre-entry location decisions, while we emphasize post-entry design incentives. We briefly discuss pre-entry design incentives in the concluding section.

Judd (1985) considers a multi-product monopolist in a model of spatial competition. In his model, entry by a single-product firm can prompt the monopolist to withdraw its nearby product offering, because a price war between close substitutes would lower margins across the incumbent's entire product line. In our model, the

[2] D'Aspremont *et al*. reconsider Hotelling's problem of location on a line, while Economides (1986) considers location on a circular city. In these setups, a firm cannot change its product location to raise its value to some consumers without also reducing its value to others. In Shaked and Sutton's model, in contrast, products have the same quality ordering among all potential customers. For our demand structure, products may or may not have a unique quality ranking among customers, and product design changes may or may not affect all consumer valuations in the same direction.

incumbent monopolist may also concede a segment of the market in response to entry. Hence, both analyses identify forces that compel the incumbent to retreat in the face of entry. The nature of the retreat differs, however, as do the consequences. For example, in our model the incumbent may retreat even when every consumer prefers the incumbent's good.

Product differentiation as a tool of price discrimination for multi-product monopolists is a central theme in many studies. Deneckere and McAfee (1996) provide several striking real-world examples, whereby the firm incurs extra costs to turn a high-end product into a lower quality version. They show that this seemingly perverse behavior can generate a Pareto improvement by raising profit, expanding the market *and* lowering the price on the high-end product. We show how entry into an initially monopolized market can lead to a non-cooperative form of price discrimination. We also show that monopoly can lead to better design incentives than duopoly.

Perloff *et al*. (1996) show that entry can cause an incumbent monopolist's price to rise or fall in a model of spatial competition. The incumbent's price declines when the entrant locates sufficiently "close" to the incumbent in product space, rises when the entrant locates farther away, and remains unchanged if the two products are sufficiently distant. Similar effects arise in our model, but our demand structure yields a different concept of distance. Our model also yields additional results; for example, an incumbent may price low to exclude the entrant, and successful entry can reduce welfare by inducing a misallocation of goods to consumers and altering design incentives.

Mussa and Rosen (1978) provide a rather different perspective on entry in a market with differentiated products. They analyze the monopoly supply of goods on a one-dimensional quality spectrum. They also compare the monopoly outcome to a competitive ideal with marginal cost pricing and positive supply at each point along an endogenous (and efficient) quality interval. Competition, unlike monopoly, maximizes efficiency and consumer surplus in their model. Thus, an idealized form of competition is better than the monopoly supply of differentiated products. For reasons outside their model, this form of competition may be infeasible or undesirable. Product development costs, fixed operating costs, transport costs and agglomeration or network effects all militate against an outcome with positive supply throughout the relevant portions of the

product space. As a result, markets with product differentiation often involve few firms producing at few locations. Limited competition of this form can yield outcomes that are inferior to monopoly, as our analysis shows.

Other related work is explicitly motivated by the low price of Microsoft Windows. Reddy *et al.* (1999) adapt the standard monopoly pricing formula to account for the follow-on sales of complementary Microsoft software applications generated by sales of Windows. They show that the monopoly price of Windows remains much higher than the observed price under reasonable assumptions about demand. Hall (2000) considers a vertical structure that emphasizes the potential for entry by downstream purchasers of Microsoft Windows such as the Dell and Compaq computer companies. Although the structure of Hall's model differs greatly from ours, he also finds that potential entry can sharply curtail the incumbent's price, and that high market share is a poor indicator of monopoly pricing power. Fudenberg and Tirole (2000) develop a model of limit pricing by the monopoly supplier of a network good. They show that the possibility of future entry encourages the incumbent monopolist to lower its current price so as to enlarge its installed customer base. In turn, a larger customer base lowers the demand facing a future entrant, which makes entry less attractive. Davis, Murphy and Topel (2001b) show that a similar motive for low pricing by an incumbent monopolist arises when consumption involves learning by doing.

3 A Model of Differentiated Products

Costs, Demand Structure, and Product Space

Consider a market with two types of consumers, one incumbent firm and, possibly, one rival who may or may not enter. Firms produce at zero marginal cost and face (avoidable) fixed operating costs of F_I for the incumbent and F_E for the entrant. Firms maximize profits, and consumers maximize consumption benefits net of prices. A firm cannot price discriminate among consumers. For now, we treat the product characteristics of the incumbent and entrant good as exogenous.

There are $N = N_l + N_h$ consumers, where $\lambda = (N_l / N_h)$ is the relative number of type-*l* consumers. Each consumer buys one or zero units of the good. Let $V_h \geq 0$ and $V_l \geq 0$ denote the benefits of the incumbent good for type-*h* and type-*l* consumers. Likewise, $W_h \geq 0$ and $W_l \geq 0$ denote consumer benefits of the entrant good. We identify type-*h* consumers by the requirement that they more highly value the incumbent good. That is, $V_h > V_l$. In this sense, we shall often refer to the two consumer groups as high-value and low-value customers with the understanding that the same ordering need not apply to the entrant good.

Parameters *V* and *W* represent locations in product space. Higher values of W_l, for example, are naturally thought of as design improvements that enhance the value of the entrant good for type-*l* consumers. However, changes in *V* and *W* also reflect any other technological or market development that alters the value of a good to one or both consumer types. As an example, let Microsoft Windows be the incumbent product, and consider a rival product (e.g., Linux) that initially offers less consumer value, because it is harder to learn how to use or less compatible with complementary products. Now suppose that new software, available at cost *c*, provides a perfect Windows emulator when layered on top of the rival product. If initially $V_h - W_h > c$ and $V_l - W_l > c$, the new "design" characteristics of the entrant good become $W_h = V_h - c$ and $W_l = V_l - c$.

The Pre-Entry Monopoly Outcome

As a useful preliminary, consider the pre-entry monopoly outcome. Provided that he covers fixed costs, the incumbent monopolist prices at $P_I^M = V_h$ and earns $\pi_I^M = V_h N_h - F_I$ when $V_h > V_l(1+\lambda)$. He prices at V_l and earns $V_l N - F_I$ when $V_h \leq V_l(1+\lambda)$. Consumer surplus is 0 when the monopolist sells only to high-value customers, and it equals $(V_h - V_l)N_h$ when he sells to both types.

The monopoly equilibrium with sales to high-value customers only is a useful analytical benchmark when entry expands market size but does not displace the incumbent. In this case, entry may reduce the incumbent price, P_I, without causing defections of type-*h* buyers to the entrant. Consumer surplus then rises. The monopoly

equilibrium with sales to both types is a useful benchmark when the entrant captures a portion of the incumbent's customer base but does not expand market size. Entry segments the market in this case, and type-*h* consumers may pay higher prices post-entry. Clearly, in a model with more consumer heterogeneity, an entrant might expand market size and capture part of the incumbent's customer base at the same time. In the two-type model that is our main focus, it is easy to isolate the market expansion and market capture aspects of entry.

Some Definitions

Individual rationality requires that consumers and firms satisfy their respective participation conditions. For consumers, participation by *h* requires $V_h \geq P_I$ or $W_h \geq P_E$. Analogous conditions hold for type-*l* consumers. A firm participates if it covers fixed operating costs in equilibrium. We assume that each firm could feasibly sell to either consumer type: $\frac{F_E}{N_l} < W_l$, $\frac{F_E}{N_h} < W_h$, $\frac{F_I}{N_l} < V_l$, $\frac{F_I}{N_h} < V_h$.

This model does not have a pure-strategy Nash (Bertrand) equilibrium in prices.[3] However, the model delivers equilibrium prices under a natural extension of the Bertrand equilibrium concept.

Definition 1 (Price Cut Immunity):

A pricing outcome $\{P_I^*, P_E^*\}$ is *price cut immune* (PCI) if:
(a) For any $P_I < P_I^*$, $\pi_I(P_I, P_E^*) \leq \pi_I(P_I^*, P_E^*)$, and
(b) for any $P_E < P_E^*$, $\pi_E(P_I^*, P_E) \leq \pi_E(P_I^*, P_E^*)$,
where $\pi_I(P_I, P_E)$ denotes incumbent profit for own price P_I and entrant price P_E, and analogously for π_E.

Price cut immunity simply means that neither firm finds it profitable to increase its sales by cutting price, given the price charged by its rival. This property holds for any Bertrand equilibrium. For a price combination to be *sustainable*, we require that it be the most profitable of all PCI combinations. That is:

Definition 2 (Sustainability):

A pricing outcome $\{P_I^*, P_E^*\}$ is *sustainable* if $\{P_I^*, P_E^*\}$ is PCI and:
(a) There is no P_I such that $\{P_I, P_E^*\}$ is PCI and $\pi_I(P_I, P_E^*) > \pi_I(P_I^*, P_E^*)$.
(b) There is no P_E such that $\{P_I^*, P_E\}$ is PCI and $\pi_E(P_I^*, P_E) > \pi_E(P_I^*, P_E^*)$.

Finally, an equilibrium is a situation in which all participants are satisfied with their choices at sustainable prices:

Definition 3 (Equilibrium):
An *equilibrium* is a set of market participation outcomes for firms and consumers, product selections by participating consumers, and prices $\{P_I, P_E\}$ such that:
(a) Consumers and firms satisfy their participation conditions;
(b) Each participating consumer buys one unit of the good that maximizes consumption benefits net of prices;
(c) $\{P_I, P_E\}$ is sustainable.

Two remarks about this equilibrium concept are in order. First, in a standard model of Nash-Bertrand price competition between two firms with differentiated products, the Bertrand equilibrium is the unique sustainable outcome under our definitions. That is, the Bertrand equilibrium is the most profitable of all outcomes that are immune from price cuts. This fact underlies the claim that our equilibrium concept is a natural extension of Bertrand equilibrium. Second, in qualitative terms, our propositions about pricing, exclusion and product design incentives also hold when the incumbent moves first in a version of the model with sequential price setting (Davis, Murphy and Topel, 2001a). Simultaneous price setting is a more compelling assumption in most applications, but it is reassuring that the results also hold under sequential pricing.

4 Post-Entry Pricing Equilibrium

Consider the requirements for a post-entry sorting equilibrium in which the incumbent sells to type-*h* consumers, and the entrant sells to type-*l* consumers;. That is,

[3] An appendix available from the authors establishes simple sufficient conditions for the non-existence of a pure-strategy Nash equilibrium in prices for a version of the model with a continuum of consumer types. Thus, non-existence does not hinge on the discrete distribution of consumer types.

focus on the case $V_h - W_h > V_l - W_l$. Both consumers and firms must be content with this sorting. For consumers this requires that type-*h* buyers prefer to purchase from *I:*

(1) $$P_I \le P_E + (V_h - W_h)$$

and that type-*l* buyers prefer *E:*

(2) $$P_I \ge P_E + (V_l - W_l).$$

On the sellers' side of the market, the incumbent must prefer selling to type-*h* buyers at price P_I to a price cut that is just sufficient to attract type-*l* buyers as well:

$$P_I N_h \ge [P_E + (V_l - W_l)](N_h + N_l),$$

or equivalently (using $\lambda = N_l/N_h$):

(3) $$P_I \ge P_E(1+\lambda) + (V_l - W_l)(1+\lambda).$$

Similarly, *E* prefers selling to type-*l* buyers at price P_E to a price cut that would attract the type-*h* buyers as well, which implies:

(4) $$P_I \le P_E \frac{\lambda}{1+\lambda} + (V_h - W_h)$$

At positive prices conditions (3) and (4) imply (1) and (2). So, if one exists, a separating equilibrium must lie in the region defined by (3) and (4), and it must satisfy the consumer participation conditions $P_I \le V_h$ and $P_E \le W_l$. Additional necessary conditions are spelled out below.

Figure 1 illustrates the situation when consumer participation constraints are slack, showing the triangular region that satisfies (3) and (4). By Definition 2, no price

combination interior to the triangular region, such as $A = \{P_I^A, P_E^A\}$, is sustainable. At combination A each seller can raise price a small amount without losing customers and without provoking a price cut from its rival. Formally, there is a $P_I > P_I^A$ such that $\{P_I, P_E^A\}$ is price cut immune and $\pi_I(P_I, P_E^A) > \pi_I(P_I^A, P_E^A)$.[4] This logic drives the pricing outcome to the intersection point $S = \{P_I^S, P_E^S\}$ that simultaneously satisfies conditions (3) and (4) as equalities. At these prices the incumbent is indifferent between selling to type-*h* buyers at price P_I^S or cutting price to $\tilde{P}_I = P_E^S + (V_l - W_l)$ to serve type-*l* buyers as well. Similarly, the entrant is indifferent between selling to type-*l* buyers at price P_E^S or cutting price to $\tilde{P}_E = P_I^S - (V_h - W_h)$ to pick off the type-*h* buyers. Algebraically, the intersection of constraints (3) and (4) is given by:

$$P_I^S = \left[\frac{\lambda}{1+\lambda+\lambda^2}\right]\left[(V_h - W_h) - (1+\lambda)(V_l - W_l)\right] + (V_h - W_h), \tag{5}$$

$$P_E^S = \left[\frac{1+\lambda}{1+\lambda+\lambda^2}\right]\left[(V_h - W_h) - (1+\lambda)(V_l - W_l)\right]. \tag{6}$$

We want to determine whether, and under what conditions, $S = \{P_I^S, P_E^S\}$ is an equilibrium. For now, we presume that both firms earn nonnegative profits at *S*.

First, consider whether $S = \{P_I^S, P_E^S\}$ is sustainable with respect to a price increase. Given P_E^S, condition (1) implies that a small price increase by the incumbent raises his profits; type-*h* consumers will still buy from the incumbent at a slightly higher price.[5] So consider an incumbent price increase to $\hat{P}_I > P_I^S$. Since condition (4) now no longer holds, the entrant is not content to sell to type-*l* buyers only. Instead, the entrant can capture the entire market by cutting price to a level slightly to the left of the boundary for condition (1), at point *B* in the Figure. This price cut raises the entrant's profits:

[4] This same argument holds for one seller at any point on the boundary of the triangular region other than point *S*.

[5] Which establishes that *S* is not a Bertrand equilibrium.

$$\begin{aligned}\underset{P_E}{Max}\{\pi_E(\hat{P}_I, P_E)\} &= \lim_{\varepsilon \to 0}\left[\hat{P}_I - (V_h - W_h) - \varepsilon\right]N - F_E \\ &= \left[\hat{P}_I - (V_h - W_h)\right]N - F_E \\ &> \left[P_I^S - (V_h - W_h)\right]N - F_E \\ &= P_E^S N_l - F_E\end{aligned}$$

where the first line follows from condition (1) and the inequality from the fact that $\hat{P}_I > P_I^S$. The last equality follows from the fact that at $S = \{P_I^S, P_E^S\}$ the entrant is indifferent between selling to type-*l*'s at P_E^S and cutting price to $P_I^S - (V_h - W_h)$ to attract the type-*h*'s. So any combination $\{\hat{P}_I, P_E^S\}$ with $\hat{P}_I > P_I^S$ is not price cut immune. By symmetry, any $\hat{P}_E > P_E^S$ also violates PCI. Hence, $S = \left\{P_I^S, P_E^S\right\}$ is sustainable with respect to a price increase by either firm.

Now consider a price decrease. Given P_E^S, the incumbent cannot capture type-*l* consumers unless he cuts price below $\widetilde{P}_I$ in Figure 1. So the incumbent earns lower profits for any price between P_I^S and $\widetilde{P}_I$, because he captures no additional customers. He earns lower profits for prices below $\widetilde{P}_I$, because the lower price more than offsets the N_l customers that he gains. The same logic applies to price cuts by the entrant. Thus $S = \left\{P_I^S, P_E^S\right\}$ is sustainable with respect to price cuts by either firm.

This argument means that a separating equilibrium is sustainable so long as both firms earn non-negative profits. We gather these results in the following proposition:

Proposition 1 (Separating Equilibrium):
Let $S = \left\{P_I^S, P_E^S\right\}$ be defined by (5) and (6). Assume that $V_h \geq P_I^S$ and $W_l \geq P_E^S$, so that consumer participation constraints are slack. If $P_I^S > \frac{F_I}{N_h}$ and $P_E^S > \frac{F_E}{N_l}$, then *S* is the unique sustainable equilibrium. The equilibrium is *separating* in that (i) firm *I* prefers to sell to type-*h* buyers at price P_I^S, (ii) type-*h* buyers prefer to purchase from firm *I* at P_I^S, (iii) firm *E* prefers to sell to type-*l* buyers at price P_E^S, and (iv) type-*l* buyers prefer to purchase from firm *E* at P_E^S.

For the case of two consumer types analyzed here, Proposition 1 does more than simply describe the separating equilibrium; it says that the separating equilibrium is the *only* sustainable outcome if it allows both firms to earn positive profits. Thus, it does not pay for one seller to cut price with the intention of excluding a rival, *if* that rival could earn positive profits in a separating equilibrium. We show below that this feature of the separating equilibrium does not extend to situations with more than two consumer types – exclusion may then be worthwhile when both sellers earn profits at separating prices.

Proposition 1 assumes slack participation constraints for consumers, and we focus on this interior case in the analysis below. However, it is straightforward to construct the separating prices when one or both consumer participations condition bind. For example, suppose that the participation condition for type-*l* consumers constrains the entrant's separating price to $P_E^{SC} = W_l$. In terms of Figure 1, W_l lies to the left of P_E^S. The same line of argument as before shows that the incumbent's separating price in this case is the highest value of P_I that satisfies (4). That is, $P_I^{SC} = W_l\left[\lambda/(1+\lambda)\right] + V_h - W_h$. Similarly, when the participation condition binds for type-*h* consumers only, the separating prices are $P_I^{SC} = V_h$ and $P_E^{SC} = [V_h/(1+\lambda)] + W_l - V_l$.

Using (5) and (6), the unique separating equilibrium also has some interesting comparative statics, which we summarize in the following proposition:

Proposition 2 (Comparative Statics for the Separating Equilibrium):

Let $S = \left\{P_I^S, P_E^S\right\}$ be defined by (5) and (6). Then:

(7) $$\frac{\partial P_I^S}{\partial V_h} = -\frac{\partial P_I^S}{\partial W_h} = \frac{(1+\lambda)^2}{1+\lambda+\lambda^2} > 1$$

(8) $$0 > \frac{\partial P_I^S}{\partial V_l} = -\frac{\partial P_I^S}{\partial W_l} = \frac{-\lambda(1+\lambda)}{1+\lambda+\lambda^2} > -1$$

(9) $$\frac{\partial P_E^S}{\partial W_l} = -\frac{\partial P_E^S}{\partial V_l} = \frac{(1+\lambda)^2}{1+\lambda+\lambda^2} > 1$$

(10) $$0 < \frac{\partial P_E^S}{\partial V_h} = -\frac{\partial P_E^S}{\partial W_h} = \frac{1+\lambda}{1+\lambda+\lambda^2} < 1$$

The results in Proposition 2 are instructive of the nature of competition between the two firms in a separating equilibrium, and they are important to our later discussion of product design incentives. For example, Equation (7) indicates that a dV_h = \$1 increase in the value of the incumbent's good to type-*h* users – to whom the incumbent sells – raises the price of the incumbent's good by more than \$1. This follows from the fact that in equilibrium $P_I^S = V_h - W_h + P_E^S \lambda/(1+\lambda)$, so an increase in V_h has a direct effect on the incumbent's price, as well as an indirect effect through the upward adjustment of the entrant's price. A higher price of the incumbent's good makes it less attractive to type-*l* users, so the entrant can raise price – equation (10) – without risk of losing customers. In contrast, equation (8) indicates that a dV_l=\$1 increase in the value of the incumbent's good to type-*l* users – to whom he does not sell in equilibrium – *reduces* the incumbent's price by less than \$1. This price reduction occurs because an increase in the value of the incumbent's good to the *entrant's* buyers forces the entrant to reduce price to retain them, which in turn forces the incumbent to cut price to retain the type-*h* users. Combining (7) and (8), a \$1 uniform-across-groups increase in the value of the incumbent's good ($dV_h = dV_l = \$1$) increases the incumbent's price, but by less than \$1. Other results in Proposition 2 follow the same logic.

Exclusionary Pricing

In some cases it pays for one firm to cut price in order to capture its rival's customers. Consistent with Proposition 1, this outcome occurs when the excluded rival would earn negative profits in the separating equilibrium, but stands ready to sell at a higher price that would cover fixed costs. We show that the excluding firm earns positive profits, and that these profits are strictly *higher* than what it would earn in the separating equilibrium. For some configurations of the parameters the identity of the excluding firm is unique, but a non-trivial portion of the parameter space yields multiple equilibria in which either the incumbent or the entrant could exclude.

What does it mean to "exclude" the entrant? In our analysis, the entrant's good represents an existing technology, valued by buyers at W_h and W_l, that is used in equilibrium if the entrant can cover fixed costs, F_E. For example, in the market for Intel-

compatible PC operating systems, original equipment manufacturers (OEM's) such as Compaq, Dell, and Gateway can pre-install an existing, non-Windows operating system such as Linux on some or all of their machines.[6] For Microsoft to preclude this possibility, the price of Windows must be low enough to make this option unattractive to OEMs.[7] Similarly, a large hub-and-spoke airline that serves business (*h*) and vacation (*l*) travelers may accommodate entry by a rival that specializes in low fares and less service, thereby conceding the type-*l*'s, or it may price low enough to make operation by an *existing* low cost carrier unattractive.

Without loss of generality, consider the incumbent's decision of whether to exclude the entrant (the analysis for the entrant is symmetric). To exclude the entrant, the incumbent must set P_I so that the entrant cannot make positive profits at any price. By condition (1), for a given P_I the entrant can capture the type-*l* customers by setting $P_E = P_I + W_l - V_l$. This generates entrant profits of $[P_I + (W_l - V_l)]N_l - F_E$. So, to exclude the entrant from profitably selling to type-*l* customers (only), the incumbent must set P_I no greater than $(F_E / N_l) + V_l - W_l$. To exclude the entrant from profitably selling to both types, the incumbent must set P_I no greater than $(F_E / N) + V_h - W_h$. The incumbent's exclusionary price is then the minimum of these two values.

This line of argument establishes the exclusionary prices P_I^x and P_E^x for the incumbent and entrant. Adopting the notation $f_E \equiv F_E / N_l$ and $f_I \equiv F_I / N_h$ for average fixed costs, we have:

$$P_I^x = \min\left\{ f_E + V_l - W_l,\ f_E \frac{1+\lambda}{\lambda} + V_h - W_h \right\}, \tag{11}$$

$$P_E^x = \min\left\{ f_I - (V_h - W_h),\ f_I \frac{1}{1+\lambda} - (V_l - W_l) \right\}, \tag{12}$$

[6] A February 2001 phone call to the customer service center at Dell Computer Corporation confirms that Dell offers pre-installed Linux operating systems on both desktop and laptop personal computers. According to Dell's web site, it is the largest seller of personal computers in the United States.

[7] Hall (2001) considers a model in which an upstream seller (Microsoft) may price low in order to preclude downstream buyers (Compaq) from developing a self-supply capability.

where $f_E \frac{1+\lambda}{\lambda} \equiv \frac{F_E}{N}$ and $f_I \frac{1}{1+\lambda} \equiv \frac{F_I}{N}$. When is it profitable for the incumbent to exclude rather than to accommodate entry? The incumbent prefers exclusion if selling to both type-*h* and type-*l* users at P_I^x is more profitable than selling to type-*h* users only in a separating equilibrium. This requires $P_I^x(1+\lambda) \geq P_I^S$. Likewise the entrant prefers exclusion if $P_E^x[1+(1/\lambda)] \geq P_E^S$.

The set of exclusionary prices is illustrated in **Figure 2**. Consider the incumbent's strategy. For any value of the entrant's average cost f_E, measured along the horizontal, equation (11) defines the set of *possible* exclusionary prices by the incumbent. These are shown as the kinked boundary (*acd*) in the figure. Suppose the entrant would earn positive profits in a separating equilibrium, as when average fixed costs are $\hat{f}_E < P_E^S$. Then the incumbent's price that would exclude the entrant is $\hat{P}_I^x$, for which $\hat{P}_I^x(1+\lambda) < P_I^S$. That is, the *incumbent* prefers the separating equilibrium to exclusionary pricing when the *entrant* would earn positive profits in the separating equilibrium. When average fixed costs are higher, such as $\tilde{f}_E > P_E^S$, the exclusionary price satisfies $\tilde{P}_I^x(1+\lambda) > P_I^S$, so the incumbent's profits are higher than in the separating equilibrium. This analysis implies that the incumbent's exclusionary price is an increasing function of the entrant's average fixed cost over the range where $f_E > P_E^S$, shown as the bold boundary (*bcd*) in the figure. By analogous argument, the entrant's exclusionary price increases with f_I over the range where $f_I > P_I^S$, shown as the bold boundary (*b'c'd'*).

The exclusionary prices shown in Figure 2 are only relevant when one or both firms earn negative profits in the separating equilibrium; otherwise Proposition 1 implies that the separating equilibrium is the unique sustainable outcome. To lay out the possibilities for exclusion, suppose first that $f_I \leq P_I^S$ -- the incumbent makes non-negative profits in the separating equilibrium -- but the entrant's average cost is $\tilde{f}_E > P_E^S$. Then by the same argument as in the previous paragraph, the incumbent prefers to capture the market at price $\tilde{P}_I^x < P_I^S$, as illustrated in Figure 2. Further, this exclusionary equilibrium is sustainable: given $\tilde{P}_I^x$, there is no price at which the entrant can attract

customers and make non-negative profit. So, if one firm would be profitable in the separating equilibrium and the other would not, the equilibrium outcome is for the profitable firm to exclude its rival at a price determined by (11) or (12).

Proposition 3 (Exclusion by the Profitable Seller):

(a) If $f_I \le P_I^S$ and $f_E > P_E^S$ the unique sustainable equilibrium is for the incumbent to exclude the entrant at an exclusionary price given by (11).[8]

(b) If $f_I > P_I^S$ and $f_E \le P_E^S$ the unique sustainable equilibrium is for the entrant to exclude the incumbent at an exclusionary price given by (12).

Proposition 3 is a special case of a more general result on profitable exclusion, which covers the case where *both* sellers would lose money in the separating equilibrium. Denote by π_I^x and π_E^x the profits that the incumbent and entrant would earn by successfully excluding the other party. By (11), the range of f_I where $\pi_I^x > 0$ depends on f_E. Focusing on the left branch of equation (11):

$$\pi_I^x \ge 0 \;\Leftrightarrow\; f_E + v_l - w_l \;\ge\; f_I \frac{1}{1+\lambda}$$

or

$$\pi_I^x \ge 0 \;\Leftrightarrow\; f_E(1+\lambda) + (v_l - w_l)(1+\lambda) \;\ge\; f_I \tag{13}$$

Similarly, using (12) the set of f_E that yield $\pi_E^x > 0$ depends on f_I:

$$\pi_E^x \ge 0 \;\Leftrightarrow\; f_E \frac{\lambda}{1+\lambda} + v_h - w_h \;\le\; f_I \tag{14}$$

Constraints (13) and (14) have the same form as (3) and (4), with the replacement of prices by average costs. Together with the region where both firms earn non-negative profits in the separating equilibrium – $\pi_I^S \ge 0$ and $\pi_E^S \ge 0$ -- they serve to divide the parameter space into four distinct regions, as shown in **Figure 3.**

[8] If the exclusionary price in (11) exceeds V_l then the price will be set at V_l. Similarly, if the exclusionary price in (12) exceeds V_h then the price will be set at V_h. We ignore these boundaries in the text for ease of exposition.

Consider the lower right region of the figure, where (13) and (14) imply that $\pi_I^x > 0$, $\pi_I^x > \pi_I^S$, $\pi_E^x < 0$, and $\pi_E^S < 0$. For cost combinations in this region, the incumbent can earn positive profits by charging an exclusionary price given by (11), which depends on the entrant's fixed cost and on buyers' willingness to pay. The incumbent's profits are greater than in the separating equilibrium, so the incumbent prefers exclusion in this region. The entrant earns negative profit, even at the price that would exclude the incumbent. So, in this region, the unique sustainable equilibrium is for the incumbent to exclude the entrant. Similar reasoning applies to the upper left region, where $\pi_E^x > 0$, $\pi_E^x > \pi_E^S$, $\pi_I^x < 0$, and $\pi_I^S < 0$; there the unique sustainable equilibrium is for the entrant to exclude the incumbent at a price given by (12).

This leaves the conical region in the center of Figure 3, where $\pi_I^x > 0$ and $\pi_E^x > 0$: in this region neither firm could cover costs when both participate, but both would earn positive profits at their respective exclusionary prices. In other words there are two possible equilibria – one where the incumbent excludes the entrant and the other where the entrant excludes the incumbent – and nothing in the model's structure allows us to choose between them.[9] This region is analogous to the situation in which two identical Bertrand competitors could sell in a particular market. Both lose money if both participate, but there is a contestable-market equilibrium in which one firm operates at a price equal to the excluded firm's average cost. With identical costs, there are two possible equilibria and the identity of the excluded firm is undetermined. There are two important differences between this situation and ours, however. First, with the demand/cost structure of our model multiple exclusionary equilibria are possible in a "large" part of the parameter space, as shown in Figure 3. Second, as we show below, *which* firm excludes in this region can have important welfare implications – unlike the standard contestable markets model, from an efficiency perspective it is not a matter of indifference which firm operates and which firm is excluded.

[9] Provided that both consumer participation constraints are slack at prices, $\left\{P_I^S, P_E^S\right\}$. As an inspection of Figure 3 readily shows, the equilibrium cannot lie in the conical region when either consumer participation condition binds.

Proposition 4 (Exclusion):

If a separating equilibrium generates negative profits for at least one firm, then the equilibrium is exclusionary. The possibilities are:

(a) $\pi_E^S < 0, \pi_E^x < 0, \pi_I^x \geq 0, \pi_I^x > \pi_I^S$: The unique equilibrium is for incumbent to exclude entrant at a price given by (11).

(b) $\pi_I^S < 0, \pi_I^x < 0, \pi_E^x \geq 0, \pi_E^x > \pi_E^S$: The unique equilibrium is for entrant to exclude incumbent at a price given by (12).

(c) $\pi_E^x \geq 0 > \pi_E^S, \pi_I^x \geq 0 > \pi_I^S$: There are two sustainable equilibria: either incumbent excludes entrant at price (11) or entrant excludes incumbent at price (12).

The result that exclusion only occurs when one or both firms earn negative profits at the separating prices is an artifact of our restriction to two consumer types. With more types, exclusion takes place in a richer set of circumstances. Consider a separating outcome with three types, *h*, *l* and *k*. Assume that $V_h - W_h > V_l - W_l > V_k - W_k$, and that both *I* and *E* can earn positive profits when *I* sells to type-*h* users and *E* sells to type-*l*, while type-*k* do not buy at the separating prices. Then an exclusionary price cut by *I* that is large enough to attract *both* type-*l* and type-*k* users can raise *I*'s profits while expanding the market to include type-*k*'s. Exclusion can also cause the market to contract. For example, with the same three types suppose *E* earns more (and positive) profit by selling to both type-*l* and type-*k* at separating prices. Then a price cut by *I* that attracts *only* the type-*l* users may drive *E* out because there are too few type-*k*'s to cover fixed cost at any feasible price.

5 Market Structure and Efficiency

Proposition 4 indicates that three market structures are possible: exclusion by the incumbent, exclusion by the entrant, or separation. In each, social surplus equals the value received by users less the fixed cost of operation. Denoting surplus in each case by S_I^x, S_E^x, and S^S, we have:

$$(15)\qquad \begin{aligned} (a)\quad & S_I^x = V_h N_h + V_l N_l - F_I \\ (b)\quad & S_E^x = W_h N_h + W_l N_l - F_E \\ (c)\quad & S^S = V_h N_h + W_l N_l - F_E - F_I \end{aligned}$$

Efficient outcomes are the maximum of (15a-c). Some algebra establishes:

$$(16)\qquad \begin{aligned} (a)\quad & S_I^x > S_E^x \Leftrightarrow f_I < V_h - W_h + \lambda(V_l - W_l + f_E) \\ (b)\quad & S^S > S_I^x \Leftrightarrow f_E < W_l - V_l \\ (c)\quad & S^S > S_E^x \Leftrightarrow f_I < V_h - W_h \end{aligned}$$

For given valuations, these conditions determine regions in (f_I, f_E)-space wherein each market structure is the efficient outcome, as shown in **Figure 4.** We have drawn the figure under the assumption that $V_h > W_h$ and $W_l > V_l$, so that separation is efficient for some positive values of f_I and f_E.

Comparison to Figure 3 indicates that combinations (f_I, f_E) for which separation is efficient form a proper subset of the region where separation actually occurs. At a point like α (β) the equilibrium outcome is separation because both *I* and *E* earn positive profits, while the efficient outcome is for *I* (*E*) to be the sole supplier at an exclusionary price. More precisely, point β illustrates a case of *inefficient entry* by *E*: entry is profitable because $f_E < P_E^S$, but entry is inefficient because fixed costs are not offset by additional value: $f_E > W_l - V_l$. This distortion of entry decisions is especially evident in the case where $V_l > W_l$. Then a separating equilibrium is never efficient – type-*l* consumers end up with a less valuable good – even though entry is profitable.

For other combinations of (f_I, f_E), the "wrong" seller may exclude – at point γ the equilibrium outcome is for the entrant to exclude the incumbent, but the efficient market structure is for the incumbent to exclude. Lastly, at points like δ the equilibrium is not unique, although the boundary $S_I^x = S_E^x$ indicates that exclusion by one party or the other is efficient.

These inefficient participation decisions occur because the efficient supplier cannot extract enough surplus at the single exclusionary price to make exclusion worthwhile. For example, at point β the incumbent earns greater profits in a separating equilibrium ($P_I^x(1+\lambda) < P_I^S$), so he concedes type-*l* users to the rival. Of course if the incumbent could price discriminate, cutting price to P_I^x for only the type-*l* buyers, then he could earn *higher* profits by excluding than by accommodating entry. Then the efficient exclusionary outcome would also be the equilibrium. More generally, if (15a) exceeds (15b) – so the incumbent is the efficient seller – then for any pair of discriminatory prices by the entrant that yield non-negative entrant profits, there are discriminatory prices by the incumbent such that (a) all buyers prefer the incumbent's product and (b) the incumbent earns positive profits. Then the efficient seller supplies the market.

Proposition 5 (Inefficient Entry and Participation):
When sellers must charge a uniform price, entry and participation decisions are generally inefficient.
In a separating equilibrium:

(a) The equilibrium is efficient if $f_I < V_h - W_h \; and \; f_E < W_l - V_l$.

(b) E inefficiently participates if $f_E > W_l - V_l \; and \; f_I < V_h - W_h + \lambda(V_l - W_l + f_E)$.

(c) I inefficiently participates if $f_I > V_h - W_h \; and \; f_I > V_h - W_h + \lambda(V_l - W_l + f_E)$.

In an exclusionary equilibrium:

(a) E inefficiently excludes if $\pi_I^x < 0 \; and \; f_I < V_h - W_h + \lambda(V_l - W_l + f_E)$

(b) I inefficiently excludes if $\pi_E^x < 0 \; and \; f_I > V_h - W_h + \lambda(V_l - W_l + f_E)$

In summary, there are two sources of deadweight loss in the event of inefficient entry: a wasteful duplication of fixed costs and a misallocation of goods to consumers. Entry can lead to either or both forms of deadweight loss.

6 Post-Entry Product Design Incentives

To this point, we have treated the valuations $V = \{V_h, V_l\}$ and $W = \{W_h, W_l\}$ as exogenous. Yet they are clearly subject to some control by sellers, who can strategically design products to affect *V* and *W*, and so affect market outcomes. Typically we think of

design decisions by the incumbent as affecting V_h or V_l, or both, while the entrant determines W_h and W_l. We focus on this case, but we also recognize that actions by one seller can affect valuations for a rival's good. For example, sellers commonly disparage rival products in an effort to reduce their value in the eyes of consumers. The design characteristics of a seller's complementary goods can also affect the value of a rival's good. Microsoft supports versions of Word and Excel that run under Apple's operating system – raising the value of the Apple platform – but allegedly made its Windows 3.1 software incompatible with rival operating systems such as DR DOS.

We focus on incentives to alter *V* or *W* and ignore the cost of design changes. As it turns out, design incentives hinge on whether a firm excludes its rival or shares the market, and on whether the firm uses the design change to exclude or to soften price competition. For example, from (11) we know that $\partial P_I^x / \partial V_l > 0$, so that a "design enhancement" that makes the incumbent's good more attractive to his rival's potential customers *raises* the price that an excluding incumbent can charge. Yet Proposition 2 established that $\partial P_I^S / \partial V_l < 0$:Once successful entry has occurred, a larger value of V_l induces the entrant to reduce price to retain his customers, which forces the incumbent to price lower to retain his as well. Thus $\Delta V_l > 0$ raises the exclusionary profits of an incumbent and reduces the range of costs over which entry is profitable ($\partial P_E^S / \partial V_l < 0$), but it reduces the incumbent's profits in the event of successful entry.

Product Design in a Separating Equilibrium

In a separating equilibrium, Proposition 2 states that firm *I* prefers design changes that increase value to type-*h* consumers ($\partial P_I^S / \partial V_h > 1$) but that do not attract its rival's customers ($\partial P_I^S / \partial V_l < 0$). Thus, an "ideal" design change for *I* is targeted at type-*h* users: $\Delta V_h > 0,\ \Delta V_l \le 0$. Similarly an ideal design change for *E* is targeted at type-*l*'s: $\Delta W_l > 0,\ \Delta W_h \le 0$.

Ideal changes of this sort may be difficult to implement, so think of a design improvement that is worth $\Delta V_h > 0$ to *I*'s targeted type-*h* users, and worth $\Delta V_l = \theta \Delta V_h$ to type-*l*'s. Here $\theta \leq 1$ measures the degree of "spillover" to the non-targeted customer group. Some algebra establishes

$$\frac{\Delta P_I^S}{\Delta V_h} = 1 + \frac{\lambda(1+\lambda)}{1+\lambda+\lambda^2}\left(\frac{N_h}{N_h+N_l} - \theta\right)$$

(17)

$$\frac{\Delta P_E^S}{\Delta V_h} = \frac{(1+\lambda)^2}{1+\lambda+\lambda^2}\left(\frac{N_h}{N_h+N_l} - \theta\right)$$

When $\theta < N_h/(N_h+N_l)$ a targeted design change increases *I's* price by *more* than the value of the improvement to type-*h* users ($\Delta P_I^S / \Delta V_h > 1$) and raises *E*'s price as well ($\Delta P_E^S / \Delta V_h > 0$). Hence, *both* consumer types are worse off because of the design change. Further, because the change in *I's* price is greater than the value of the design improvement, there is a clear incentive for excessive product differentiation.

Proposition 6 (Targeted Design Changes in a Separating Equilibrium):

Consider a targeted design change by firm *I* $\{\Delta V_h > 0, \Delta V_l = \theta \Delta V_h\}$, with $\theta \leq 1$. The effects on prices and consumer welfare depend on the amount of spillover, θ. If $\theta < N_h/(N_h+N_l)$ then:

1. $\Delta P_I^S / \Delta V_h > 1$ and $\Delta P_E^S / \Delta V_h > 0$: Prices charged by both sellers rise, and the price to type-*h* users rises by more than their value of the design improvement.
2. Consumer surplus falls for all users.
3. Incentives support excess product differentiation.

Design flexibility leads to excess product differentiation in the separating equilibrium, because firms use it as a tool to soften price competition. The effect is to transfer surplus from consumers to producers and to distort the path of innovation relative to the criterion of consumer or total surplus.

In some settings, design flexibility may be sharply circumscribed by technological or other considerations that dictate the "direction" of product design changes. The following proposition deals with this case.

Proposition 7 (Innovation Along a Fixed Path in a Separating Equilibrium): Assume that incremental product improvements occur along fixed innovation paths defined by the ratios $\Delta W_h/\Delta W_l$ for the entrant and $\Delta V_l/\Delta V_h$ for the incumbent.

A. **(Innovation Incentives)** Own product improvements are profitable for the entrant if $\Delta W_h/\Delta W_l < 1+\lambda$ and for the incumbent if $\Delta V_l/\Delta V_h < (1+\lambda)/\lambda$

B. **(Consumer Surplus)** Innovation by the entrant raises consumer surplus if

$$\frac{\Delta W_h}{\Delta W_l} > \frac{\lambda(1+2\lambda)}{1+3\lambda+2\lambda^2}$$

Innovation by the incumbent raises consumer surplus if

$$\frac{\Delta V_l}{\Delta V_h} > \frac{2+\lambda}{2+\lambda+\lambda^2}$$

Proof: Part A follows directly from equations (5) and (6). To prove the first part of B, use (5) to show that the impact on surplus for type-*h* consumers is proportional to $(1+2\lambda+\lambda^2)\Delta W_h - \lambda(1+\lambda)\Delta W_l$. Use (6) to show that the impact on surplus for type-*l* consumers is proportional to $(1+\lambda)\Delta W_h - \lambda\Delta W_l$ for the same factor of proportionality. Since $\lambda = N_h/N_l$, the impact on overall consumer surplus is proportional to $(1+3\lambda+2\lambda^2)\Delta W_h - \lambda(1+2\lambda)\Delta W_l$, which yields the result. Similar calculations yield the second part of B.

A simple example draws out the implications of Proposition 7. When $\lambda = 1$, incremental innovation by the entrant is profitable for $\Delta W_h/\Delta W_l < 2$, and it raises consumer surplus for $\Delta W_h/\Delta W_l > 3/5$. Hence, in this example, the entrant would forego a no-cost product improvement that raises consumer and total surplus, if $\Delta W_h/\Delta W_l > 2$. Similarly, the incumbent's innovation incentives in this example are adverse to consumer interests for $\Delta V_l/\Delta V_h \in (0,.75]$, and they are adverse to total surplus for $\Delta V_l/\Delta V_h > 2$.

Thus, even when technology constrains the product design path, a firm's innovation incentives can easily run counter to the interests of consumer welfare or total surplus in a separating equilibrium. Firms will forego no-cost design improvements, if they intensify price competition too much.

Exclusion by Product Design

When both firms earn profits at the separating outcome, neither firm adopts an exclusionary price in the model with only two consumer types. Yet, even in this case, exclusionary strategies based on product design changes *can* be profitable, as we now show. By definition, a successful exclusionary strategy must (a) raise the excluding firm's profits, so that exclusion is preferred, and (b) preclude the rival from earning profits. If we treat firm *I* as the excluding seller, these conditions require

$$\Delta\pi_I = \hat{\pi}_I^x - \pi_I^S = N_h(\hat{P}_I^x(1+\lambda) - P_I^S) > 0$$

$$\hat{\pi}_E^S = N_l(\hat{P}_E^S - f_E) < 0$$

where a '$\wedge$' over a variable indicates its post-design-change value. We consider design changes that satisfy these conditions. We assume that the entrant can avoid its fixed costs by withdrawing from the market in response to the incumbent's design change.

By Proposition 2, there are 4 possible ways to reduce *E*'s price and drive him from the market: $\Delta V_l > 0$, $\Delta W_l < 0$, $\Delta V_h < 0$, and $\Delta W_h > 0$. Of these, we can rule out strategies based on $\Delta V_h < 0$ and $\Delta W_h > 0$ because they do not increase the exclusionary price that *I* can charge after driving *E* out, so $\Delta\pi_I < 0$. For example, suppose that *I* degrades his product, reducing V_h by enough to drive *E* out. Since $\Delta V_h < 0$ does not raise the exclusionary price, and $(1+\lambda)P_I^x < P_I^S$, $\Delta V_h < 0$ cannot be profitable.

The strategies that can both reduce P_E^S and raise P_I^x are $\Delta V_l > 0$ and $\Delta W_l < 0$. $\Delta V_l > 0$ is an "own product" competitive design improvement that is targeted at *E*'s

customer base. In contrast, $\Delta W_l < 0$ is a form of strategic "sabotage" in which *I* degrades the value of *E*'s product to type-*l* users.

Suppose *I* attacks *E*'s customer base with $\Delta V_l = \hat{V}_l - V_l > 0$. The change in *I*'s profit from successful exclusion is

$$\begin{aligned}\Delta\pi_I &= N_h[(f_E + \hat{V}_l - W_l)(1+\lambda) - P_I^S] \\ &= N[-(P_E^S - f_E) + \hat{V}_l - V_l]\end{aligned}$$

The term $P_E^S - f_E$ is *E*'s profit per customer in the separating equilibrium. In driving *E* out, *I* must transfer this surplus to *all* buyers. The second term, $\hat{V}_l - V_l$, is the increase in the exclusionary price that *I* can charge once *E* is driven out. Hence, the change in *I*'s profit is positive only for sufficiently large values of $\hat{V}_l - V_l$.

In particular, let $\hat{V}_l - V_l \equiv (\overline{V}_l - V_l) + (\hat{V}_l - \overline{V}_l)$, where $\overline{V}_l - V_l$ is the minimum necessary improvement that drives *E*'s profits to zero. Then

$$\begin{aligned}\Delta\pi_I &= N[-(P_E^S - f_E) + \hat{V}_l - V_l] = N[1 - \frac{(P_E^S - f_E)}{\overline{V}_l - V_l}](\overline{V}_l - V_l) + N(\hat{V}_l - \overline{V}_l) \\ &= N_h \frac{\partial P_I^S}{\partial V_l}(\overline{V}_l - V_l) + N(\hat{V}_l - \overline{V}_l)\end{aligned} \tag{18}$$

A successful exclusionary design change has two effects on profits. The first term in (18) is the change in profit from a design change that is just sufficient to exclude ($\hat{V}_l = \overline{V}_l$). This term is negative because $\frac{\partial P_I^S}{\partial V_l} < 0$. Intuitively, exclusion by product design drives down the separating prices of *both* sellers, so a design change that is just sufficient to exclude *E* cannot be profitable.[10] The second term is *I*'s gain from a higher exclusionary

[10] Recall that in the separating equilibrium each seller is indifferent between charging its separating price and cutting price to the level that would exclude: $P_I^x(1+\lambda) = P_I^S$. So when $\hat{V}_l = \overline{V}_l$, the incumbent is indifferent between exclusion and separation.

price to all buyers *once E is driven out*. This component must be large enough to offset the "cost" of exclusion, as represented by the first term.

Analysis of exclusion by "sabotage" ($\Delta W_l < 0$) is similar. The change in *I*'s profits from successful exclusion is

$$\begin{aligned}\Delta\pi_I &= N[-(P_E^S - f_E) + W_l - \hat{W}_l] \\ &= N_h \frac{\partial P_I^S}{\partial W_l}(\overline{W}_l - W_l) + N(\overline{W}_l - \hat{W}_l)\end{aligned} \tag{19}$$

where $\overline{W}_l - W_l < 0$ is the minimum amount of sabotage necessary to eliminate *E*'s profits. Again, driving *E* out carries a cost because $\frac{\partial P_I^S}{\partial W_l} > 0$. This cost must be offset by the term $N(\overline{W}_l - W_l) > 0$, representing revenues from the higher exclusionary price that *I* can charge after *E* is driven out. Again, the total amount of sabotage must be large enough to offset the cost of exclusion.

The effects of successful exclusion on consumer welfare depend on whether the strategy pursued by *I* is an own-product design improvement ($\Delta V_l > 0$) or sabotage ($\Delta W_l < 0$). If the former, consider a targeted design innovation $\Delta V_l = \hat{V}_l - V_l$ and its associated spillover $\Delta V_h = \hat{V}_h - V_h$. The change in surplus for type-*l* users is:

$$\begin{aligned}\hat{S}_l - S_l &= \hat{V}_l - W_l - (\hat{P}_I^x - P_E^S) \\ &= \hat{V}_l - W_l + P_E^S - Min\{f_E + \hat{V}_l - W_l, f_E \frac{\lambda}{1+\lambda} + \hat{V}_h - W_h\} \\ &\geq \hat{V}_l - W_l + P_E^S - (f_E + \hat{V}_l - W_l) \\ &= P_E^S - f_E \geq 0\end{aligned} \tag{20}$$

So type-*l* users – who purchased from *E* prior to exclusion – must gain from a product innovation that excludes *E* from the market. In effect, the per-unit profits that were earned by *E* are transferred to type-*l* users, who now purchase the "improved" version of *I*'s good. For type-*h* users:

$$
\begin{aligned}
\hat{S}_h - S_h &= \hat{V}_h - V_h - (\hat{P}_I^x - P_I^S) \\
&= \hat{V}_h - V_h + P_I^S - Min\{f_E + \hat{V}_l - W_l, f_E \frac{\lambda}{1+\lambda} + \hat{V}_h - W_h\} \\
&\geq \hat{V}_h - V_h + P_I^S - (f_E \frac{\lambda}{1+\lambda} + \hat{V}_h - W_h) \\
&= P_I^S - f_E \frac{\lambda}{1+\lambda} - (V_h - W_h) \\
&= \frac{\lambda}{1+\lambda}(P_E^S - f_E) \geq 0.
\end{aligned} \tag{21}
$$

Type-*h* consumers also benefit from an innovation that excludes *E*. Thus, *own-product design changes that lead to successful exclusion are welfare improving for both consumer types.*

In contrast, successful sabotage reduces the welfare of type-*l* users, but it may be welfare improving for type-*h*. The former effect occurs because $\Delta W_l < 0$ raises the exclusionary price that type-*l*'s must pay, without raising the value of the good that they consume in the exclusionary equilibrium. Formally,

$$
\begin{aligned}
\hat{S}_l - S_l &= V_l - \hat{P}_I^x - (W_l - P_E^S) \\
&= \frac{1}{1+\lambda}[P_I^S - (1+\lambda)\hat{P}_I^x]0 \\
&= -\frac{1}{1+\lambda}\frac{\Delta\pi_I}{N_h} \leq 0.
\end{aligned} \tag{22}
$$

so *I*'s gain in profit is a loss to type-*l* users. For type-*h* users the change in welfare is determined by whether price rises or falls with exclusion:

$$
\begin{aligned}
\hat{S}_h - S_h &= P_I^S - \hat{P}_I^x = [P_I^S - (1+\lambda)\hat{P}_I^x] + \lambda\hat{P}_I^x \\
&= -\frac{\Delta\pi_I}{N_h} + \lambda\hat{P}_I^x
\end{aligned} \tag{23}
$$

The first term is non-positive, as *I* must prefer exclusion. But profitable sabotage still leaves room for type-*h*'s to gain because the exclusionary price is likely to be lower than P_I^S. Design sabotage that is just worthwhile for the incumbent ($\Delta\pi_I = 0$) *always*

improves welfare for type-*h* users because exclusion leads to a lower price. Unlike the case of own-product design changes ($\Delta V_l > 0$), when exclusion is achieved by competitive sabotage ($\Delta W_l < 0$) the interests of consumer groups are not aligned.

Proposition 8 (Exclusion by Product Design):

Beginning from a separating equilibrium, seller *I* may profitably exclude its rival by either own product design improvements that are targeted at *E*'s customer base ($\Delta V_l > 0$), or by design sabotage that reduces the value of *E*'s good ($\Delta W_l < 0$). When these design changes are large enough to yield profitable exclusion:

1. Own product design changes $\Delta V_l > 0$ increase consumer welfare for both type-*l* and type-*h* users.

2. Competitive sabotage $\Delta W_l < 0$ reduces welfare for type-*l* users, but will raise welfare for type-*h* users if price falls with exclusion ($\hat{P}_I^x < P_I^S$).

7 Price Effects of Entry

In a standard industry model where competing firms sell perfect substitutes, entry of a new seller reduces the price charged by all sellers and raises overall welfare. For example, if the market was initially monopolized, the entry of a new non-cooperative seller would yield a lower price and greater industry output. These clean predictions need not hold when competing sellers produce differentiated products for diverse buyers, however. In our model, the incumbent firm may react to entry by raising price, and both consumer and total surplus may fall.

We now reserve the term "entry" for situations where a new seller makes positive sales in the market under study. This happens when $P_E^S \geq f_E$ in a separating equilibrium, or when the entrant displaces the incumbent by charging an exclusionary price. Entry can occur for three reasons:

1. A new rival emerges with $\{f_E, W_h, W_l\}$. The rival can affect the incumbent's price either because the incumbent chooses to exclude or because entry is profitable: $P_E^S \geq f_E$.

2. The costs of participating for an existing product, f_E, decline by enough to make entry worthwhile for given valuations V and W.

3. Valuations V and W change in such a way that entry becomes worthwhile for a given cost of participating.

We treat these cases in turn.

Emergence of a New Product

Consider a new product that, absent competition, could survive by selling to type-l users; $f_E < W_l$. For brevity, focus on the case where $V_h > V_l$ and $V_h - V_l > W_h - W_l$. According to Figure 3, there are at least three possible outcomes: (i) the incumbent excludes the new product at a price given by (11); (ii) both firms participate at prices $\{P_I^S, P_E^S\}$; (iii) the entrant excludes at a price given by (12).[11] The last outcome has implications for efficiency, which we take up below, but not for the incumbent's price.

If the incumbent prices to exclude, then (11) implies that $P_I^x \le f_E + V_l - W_l < V_l$. If $V_h > V_l(1+\lambda)$ then the incumbent monopolist had previously sold to type-h users only at price V_h. In this case, the new product causes price to fall while expanding unit sales of the incumbent's good. If $V_h < V_l(1+\lambda)$ then the incumbent monopolist's price had been V_l, so that price falls without affecting unit sales. In either case, the new product causes a fall in the incumbent's price. When $f_E > W_l$, the entrant could survive by selling to both types if $f_E\lambda/(1+\lambda) < W_l$. The incumbent's exclusionary price is then $P_I^x = f_E\lambda/(1+\lambda) + V_h - W_h < V_l$, so price must fall in this case as well. Finally, by a similar analysis, one can also show that price falls when the entrant can only survive by selling to type-h users. In summary, when the emergence of a new product elicits an exclusionary pricing response, price must fall below the monopoly level.

If the new product is profitable in a separating equilibrium, entry occurs. If the incumbent was originally pricing at V_h, then we know that the incumbent's price cannot rise, and it must fall if consumer participation constraints are slack at the post-entry

[11] Two other outcomes are also possible. First, entry can be ineffectual in the sense that the incumbent excludes the entrant while continuing to price at the monopoly level. Second, both firms participate, but one or both consumer participation conditions bind. The first possibility is trivial, and the second possibility has similar implications to the interior separating case considered in the text.

outcome because $P_I^S < V_h$. If monopoly demand was elastic, however, the incumbent originally sold to both types at price V_l. In this case, the separating equilibrium involves incumbent sales to type-*h* only, possibly at a higher price $P_I^S > V_l$. In effect, the incumbent "retreats" up market, selling only to consumers with high willingness to pay for his product.

Proposition 9 (Incumbent's Price with Successful Entry of a New Product): Successful entry by the seller of a new product causes an incumbent monopolist to reduce price if $P_I^M = V_h$. Entry may cause the incumbent to raise price if $P_I^M = V_l$.

Some numerical examples illustrate the range of possible pricing responses to the introduction of a rival product. Suppose that $V_h = 9,\ V_l = 5,\ W_h = 3$ and $N_h = N_l = F_I = F_E = 1$, so that the incumbent prices at 5 and sells to both types prior to entry. When $W_l < 1$, the new product has no effect, because it is not attractive enough to influence the equilibrium. For $W_l \in (1, 2.75),$ entry induces an exclusionary pricing response by the incumbent. The new product then has no effect on allocations, but it benefits consumers by depressing the incumbent's price.[12] When $W_l > 2.75,$ exclusionary pricing by the incumbent is too costly in terms of foregone revenues. So, the incumbent retreats up market, allowing the entrant to capture the type-*l* consumers. In this example, the incumbent raises price above the exclusionary level *and* above the pre-entry monopoly level. In contrast, if $W_h = 6,$ then the new product leads to a separating outcome with an incumbent price below the monopoly price for all $W_l \in (4.25, 6.5)$.

A good real-world example of Proposition 9 occurs when the patent expires on a "brand name" prescription drug. A generic manufacturer may then market a chemical copy of the patented drug. Although the generic and branded drugs have identical active ingredients, the branded version typically sells for a large premium. These facts are implied by our model when $V_h - W_h > (V_l - W_l)(1+\lambda)$, so that a separating equilibrium is

[12] One can modify the example to include a third consumer type that places low value on the incumbent's good and does not buy in the monopoly outcome. For suitable parameters, the entrant sells to the third type,

feasible. As we discussed in the introduction, the evidence on the direction of post-entry price changes for brand name drugs is mixed – sometimes they rise, sometimes they fall. This evidence is consistent with Proposition 9.

Entry of an Existing Technology

Proposition 9 indicates that an incumbent may raise price in the face of successful entry by a new product. This outcome is more likely when the entrant produces an existing technology that was previously excluded by the incumbent. To achieve entry of a previously excluded product, either the costs of participating must fall or product design parameters must change so that participation by the entrant becomes profitable.

Consider the case where the entrant's fixed cost of participation, f_E, declines, leaving valuations unchanged. Recall that the incumbent's exclusionary price is

$$P_I^x = \min\left\{ f_E + V_l - W_l,\ f_E \frac{1+\lambda}{\lambda} + V_h - W_h \right\},$$

which is shown in Figure 5. If fixed costs are so high that P_I^x is given by the second term in brackets, then inspection of Figure 5 shows that $P_I^S < P_I^x$, and the incumbent's price falls upon entry. But, if the exclusion margin initially involves the type-*l's* only, so that $P_I^x = f_E + V_l - W_l$, then the incumbent's price can rise or fall with entry. Some algebra establishes the critical level $f_E^* = (1+\lambda)P_E^S + \lambda(V_l - W_l)$, shown in Figure 5, that determines whether $P_I^S > P_I^x$. All values of $f_E < f_E^*$ imply $P_I^S > P_I^x$, so that the incumbent's price rises in the face of successful entry caused by a decline in entrant fixed costs. Inspecting the figure establishes that the incumbent's price rises with entry when the pre-entry level of f_E is not "too large".

Proposition 10 (Entry due to a Decline in the Rival's Fixed Costs):
When the incumbent seller prices to exclude the entrant, a sufficiently large decline in f_E may lead to entry and a separating equilibrium. The incumbent's price rises (falls) upon entry if the original level of f_E is smaller (larger) than $f_E^* = (1+\lambda)P_E^S + \lambda(V_l - W_l)$.

---

while eliciting an incumbent price that excludes sales of the new product to type-*h* and type-*l* consumers. Thus, exclusionary pricing need not involve 100 percent market share for the leading firm.

Another, perhaps more interesting, scenario involves design changes that make entry profitable. For example, an excluded entrant can alter W_h or W_l and thereby affect its post-entry price. Since $\partial P_E^S / \partial W_l > 0$ and $\partial P_E^S / \partial W_h < 0$, an "ideal" design improvement from the entrant's perspective is one that targets consumers who will buy his product in equilibrium ($\Delta W_l > 0$), without raising the valuations of his rival's customers ($\Delta W_h \leq 0$). A design improvement of this type increases the separating prices of both firms, and the resulting entry *must* raise the incumbent's price above the pre-entry exclusionary price. This can be seen in Figure 5. For any cost of participation such as $\hat{f}_E > P_E^S$ that blocks profitable entry, there is a $\Delta W_l > 0$ that would make entry profitable. The resulting equilibrium values of P_I^S must lie on constraint $V_h - W_h + f_E \frac{\lambda}{1+\lambda}$ to the right of $\hat{f}_E$, which satisfy $P_I^S > \hat{P}_I^x$. Similarly for discrete changes $\Delta V_h > 0$ that raise both separating prices along the constraint $(V_l - W_l + f_E)(1+\lambda)$, the incumbent's post-entry value of P_I^S must exceed his pre-entry exclusionary price.

As we argued above, such "ideal" product design changes may not be feasible. So assume that the potential entrant implements a design improvement $\Delta W_l > 0$ with spillover $\Delta W_h = \phi \Delta W_l > 0$. The entrant's incentive to avoid direct competition for the incumbent's base suggests $\phi < 1$, but this is not necessary. Then the ratio of separating price changes is:

$$\frac{\Delta P_I^S}{\Delta P_E^S} = \frac{\lambda - (1+\lambda)\phi}{1+\lambda-\phi}$$

This slope defines a vector starting from $S = \{P_I^S, P_E^S\}$ that gives the set of *new* separating prices that are consistent with attribute changes $\Delta W_l > 0$ and arbitrary ϕ, as shown in **Figure 5**. The impact of entry on the incumbent's price is determined by whether this line lies above or below the incumbent's original exclusionary price function at the *new*, feasible value of P_E^S. The smaller is ϕ, the greater the range of feasible P_E^S where the

incumbent's price must rise with entry, and when ϕ=0 the incumbent's price rises unambiguously.

Proposition 11 (Entry due to Improved Product Attributes):
An excluded seller may achieve entry by product improvements that yield $P_E^S > f_E$. If changes in valuations apply only to type-*l* users ($\Delta W_l > 0$, $\Delta W_h = 0$), the incumbent's price rises with entry. If changes in valuations apply to both user types ($\Delta W_l > 0$, $\Delta W_h > 0$), then the incumbent's price may rise or fall with entry.

8 Multi-Product Monopoly

To this point, our analysis considers the post-entry equilibrium relative to outcomes for a single-product monopolist. Another natural market structure to consider is a monopolist who occupies both locations in product space. The multi-product monopolist maximizes profit over prices, P_I^M and P_E^M, subject to the consumer participation and product selection conditions.

Figure 6 depicts the opportunity set for the multi-product monopolist. Given V_h - $W_h > V_l$ - W_l, the consumer product selection conditions (1) and (2) define a nonempty region bounded by the solid parallel lines in the figure. Profitability requires positive prices. Recalling the definitional condition $V_h > V_l$, the participation condition for type-*h* consumers further restricts the opportunity set to points on or below the horizontal line at V_h. When $W_l < W_h$, the participation boundary for type-*l* consumers is a vertical line that intersects condition 1 at a point like A, so that the opportunity set is defined by a parallelogram. When $W_l \geq W_h$, the participation boundary for type-*l* consumers is a vertical line that intersects the $P_I^M = V_h$ line at a point like B, so that the opportunity set is defined by a quadrilateral. Hence, a multi-product monopolist who segments the market maximizes profit by pricing at a point like A or B, as W_l is smaller or larger than W_h.

Making use of Figure 6, we characterize multi-product monopoly outcomes and compare them to the duopoly market structure in an appendix. There are two main results. First, different market structures give rise to a misallocation of goods in different regions of the parameter space. For this reason, it is not possible to uniformly rank alternative market structures – monopoly versus two competing firms – by the criterion

of allocative efficiency or total surplus. For the same reason, but perhaps more surprisingly, the two market structures cannot be uniformly ranked by the criterion of consumer surplus. For some parameter values, the loss of consumer surplus engendered by an inefficient allocation in a two-firm separating equilibrium more than offsets the effect of monopoly pricing on consumer welfare. As a result, consumer surplus can be greater under monopoly than with two competing firms.

Second, the adverse design incentives that arise under duopoly can also arise under multi-product monopoly. However, adverse incentives are weaker under multi-product monopoly in two respects. One, the incentive for quality degradation arises in a smaller region of the parameter space. Two, even in that region, the monopolist benefits from quality degradation in only one, not two, directions. Multi-product monopoly also implies less scope for adverse design incentives when technology dictates the direction of innovation. Monopoly design incentives are better aligned with economic efficiency, because a single firm can more readily extract surplus (without resorting to inferior product designs) than two firms that price non-cooperatively.

9 Concluding Remarks

We have analyzed the effects of entry into an initially monopolized market on price, efficiency and consumer welfare. For given product design characteristics, entry can be beneficial by expanding the market or lowering prices. But successful entry can also cause the incumbent to raise price as he concedes part of the market, harming some consumers. When entry undermines an exclusionary pricing regime, it can raise price and lower surplus for all consumers. These adverse effects of entry do not arise with a homogeneous product but can easily happen with differentiated products. In segmenting the market, successful entry can also induce an inefficient allocation of goods. Given the potential for higher prices and a misallocation of goods, successful entry does not ensure gains in consumer welfare or total surplus.

Unsuccessful entry can be highly beneficial to consumers. Consumers benefit when the entrant, even though unsuccessful in the sense of market share, elicits an exclusionary pricing response by the incumbent. This type of aggressive pricing also arises when the incumbent seeks to prevent an existing rival in an adjacent market from

capturing part of the incumbent's market. Either way, the incumbent retains his entire market only by pricing low enough to preclude sales by actual or potential rivals. Exclusion can also take place through strategic product design choices, or through a combination of pricing and design choices. Exclusionary own-product improvements always raise consumer surplus in our model.

Once established, the presence of an entrant creates strong incentives for each firm to differentiate its product in ways that soften price competition. Greater differentiation leads to higher prices for both goods and lower consumer surplus. Thus, there is a stronger presumption that entry-induced segmentation leads to higher prices once we account for its impact on product design incentives. This point has greater force for products like software that exhibit considerable design flexibility.[13] The flexibility enables firms to tailor product specifications to appeal more strongly to existing customers than to the rival's customers, perhaps by not upgrading the product design along dimensions that are relatively highly valued by the rival's customers.

When technology dictates the path of design changes, a separating equilibrium may or may not involve favorable innovation incentives. For example, a firm may forego socially beneficial product improvements, even when they are cost free. This outcome is more likely when product enhancements are less attractive to the firm's existing customers than to its rival's customers. The firm shies away from product improvements in this case, because they intensify price competition too much. It can also be profitable, given a fixed innovation path, for the firm to pursue product improvements that lower consumer surplus. Ironically, this outcome is more likely when product enhancements are relatively attractive to the firm's existing customers. In this case, product improvements soften price competition, amplifying the firm's incentive to innovate.

Entry and potential entry have additional effects on pricing, consumer surplus and efficiency in a dynamic setting. For instance, the costs of learning to use a new product and other complementary investments create switching costs for consumers. If supply-side scale economies are also present, then an incumbent can discourage future entry by pricing low. A low price expands the incumbent's current customer base and thereby soaks up some of the future demand facing a prospective entrant. Product-level network

[13] See Davis, MacCrisken and Murphy (2001) on software design flexibility and its implications.

effects also give rise to an entry-deterrence motive for low pricing, as analyzed by Fudenberg and Tirole (2000).

While potential entry can depress the incumbent's price in a dynamic setting through an entry-deterrence motive, actual entry tends to undermine this motive. In an environment that will sustain only a few firms, actual entry reduces the scope for further entry and thereby relaxes the entry-deterrence motive. We provide examples of this effect in Davis, Murphy and Topel (2001b), where we analyze the pricing effects of actual and potential entry in a dynamic version of our model with consumer learning by doing. The relaxation of the entry-deterrence motive is distinct from the adverse price effects of entry analyzed in this paper: market segmentation, retreat from exclusionary pricing, and adverse design incentives. All of these effects are potentially important sources of upward price pressure in the face of entry into an initially monopolized market.

Much of our analysis focuses on post-entry incentives to soften price competition in a separating equilibrium. Firms accomplish this goal by moving away from each other in product space. Prior to entry, however, an incumbent monopolist has at least two reasons to design a product with broad consumer appeal. First, a design with broad appeal is more likely to substitute closely with a potential entrant's offering. Nearness in product space leads to sharper price competition in the post-entry equilibrium. If prior design attributes place some limits on later design choice, then a product with broad appeal can help the incumbent commit to more intense pricing competition post entry. In turn, the prospect of more intense price competition discourages entry. In this way, an incumbent design with broad appeal makes entry less attractive.[14]

Second, by raising current unit sales, a design with broad appeal soaks up some of an entrant's potential future demand. Thus, given consumer switching costs and supply-side scale economies, an incumbent design with broad consumer appeal makes it harder for an entrant to capture a profitable market presence. Similarly, given network effects on the demand side, a design with broad appeal makes it harder for an entrant to obtain a toe-hold in the market. In these respects, a design with broad appeal is attractive to the

[14] This motive for a product design with broad appeal is similar to the motive for brand proliferation in Schmalensee (1978) and Eaton and Lipsey (1979). It is also subject to the qualification stressed by Judd (1985): credible entry deterrence rests on incumbent exit costs. In our context, this means the cost of retreating from a design with broad appeal.

incumbent for the same reason as a low price—both help to soak up the future demand for a potential entrant's product.

In short, potential entry also influences a monopolist's product design decisions. Unlike the design incentives induced by actual entry, potential entry encourages the incumbent to select designs with broad consumer appeal. For similar reasons, a leading firm has strong incentives to innovate in directions that respond to the nascent competitive threats posed by potential rivals. “Me-too” enhancements or other suitably targeted design improvements by an incumbent can limit the appeal of a potential rival's product. As a result, suitably targeted design improvements may enable an incumbent to ward off the threats presented by potential rivals, or to deter a potential rival from competing directly with the incumbent. Furthermore, insofar as targeted design improvements of this sort enable an incumbent monopolist to maintain an exclusionary pricing policy, they can be highly beneficial for consumers. Consumers benefit directly from better products and indirectly as the product improvement makes it attractive for the incumbent to continue pursuing an exclusionary pricing policy.

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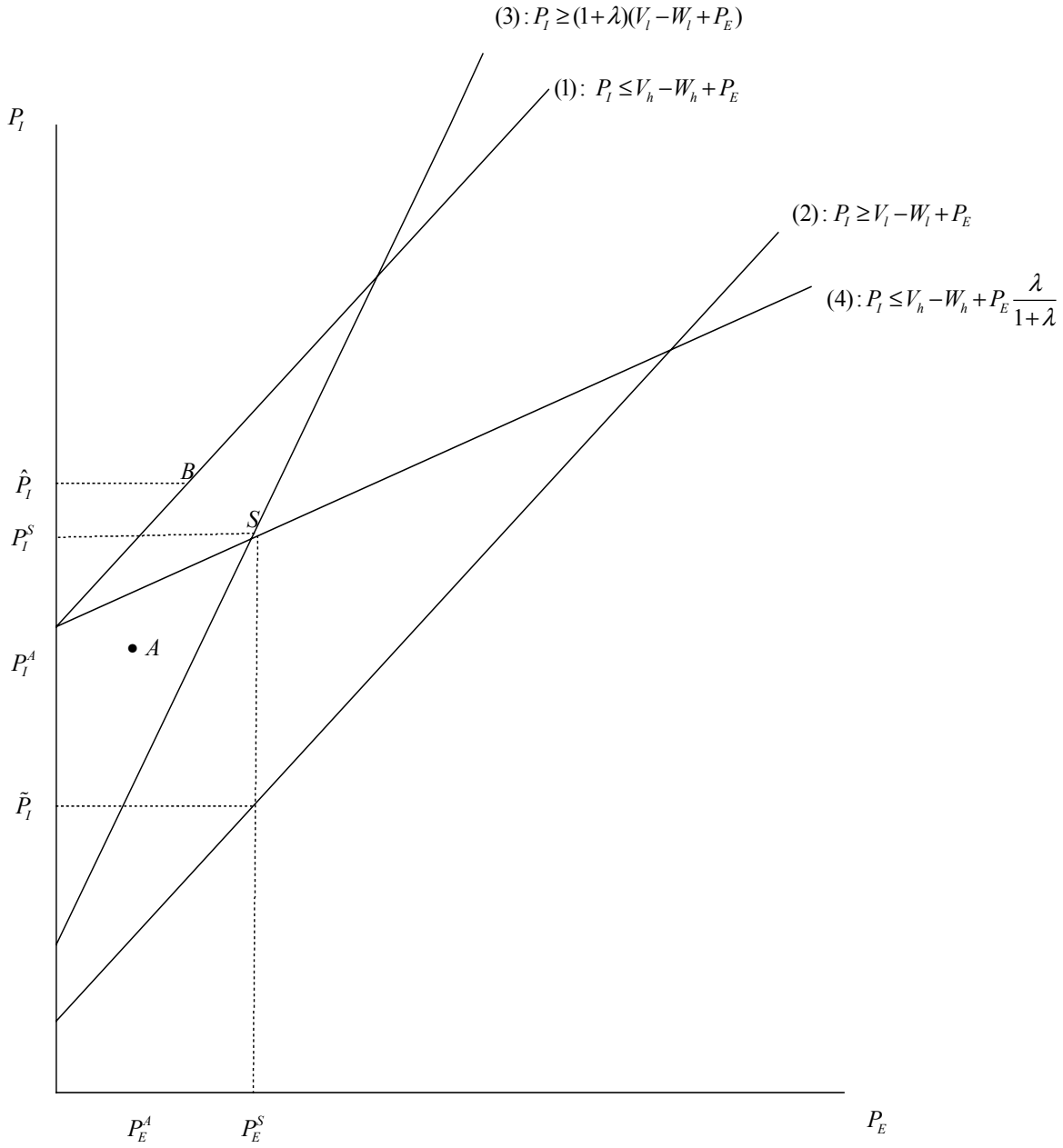


Figure 1
Prices in a Separating Equilibrium

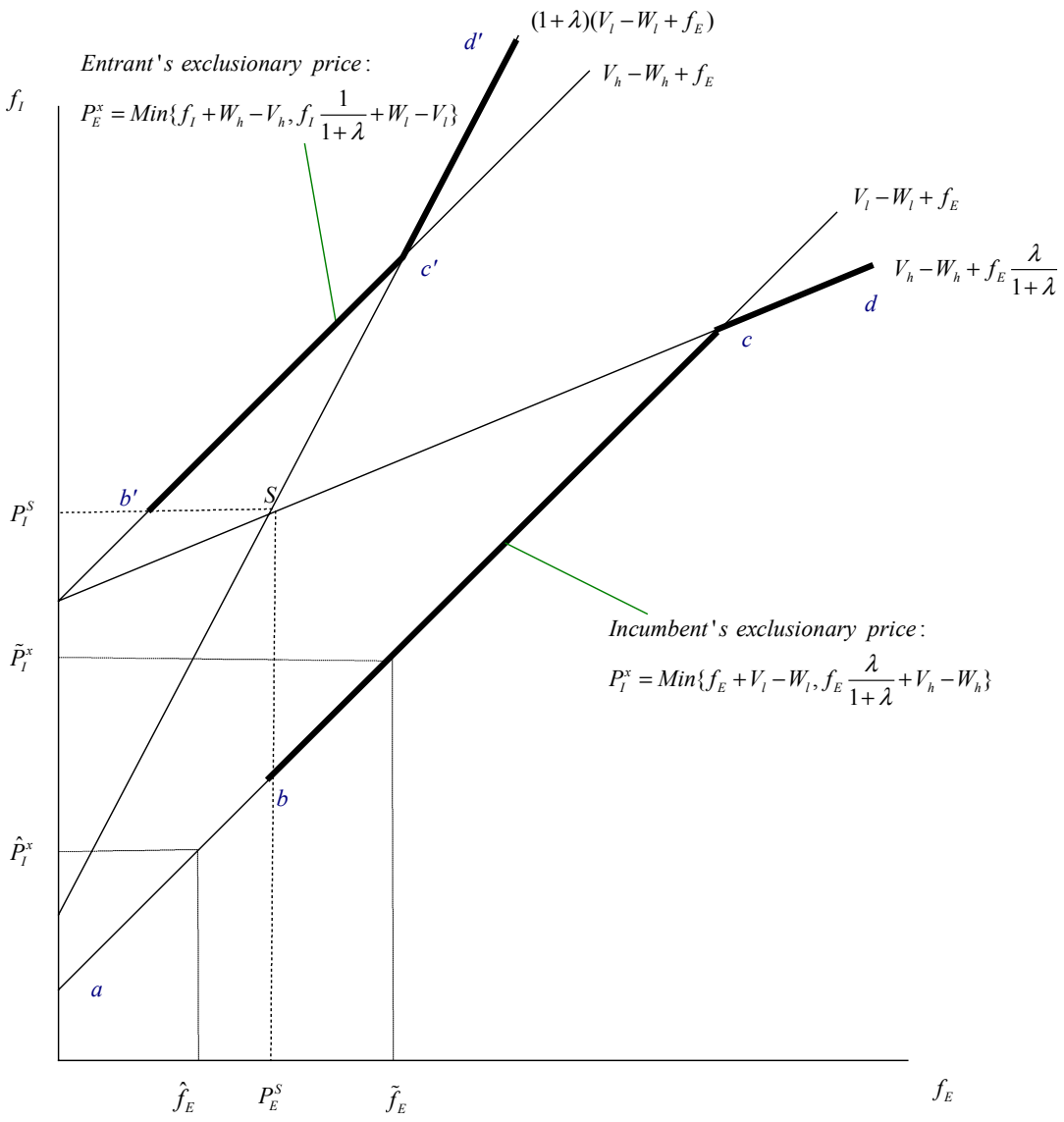


Figure 2
Exclusionary Prices for the Incumbent and Entrant

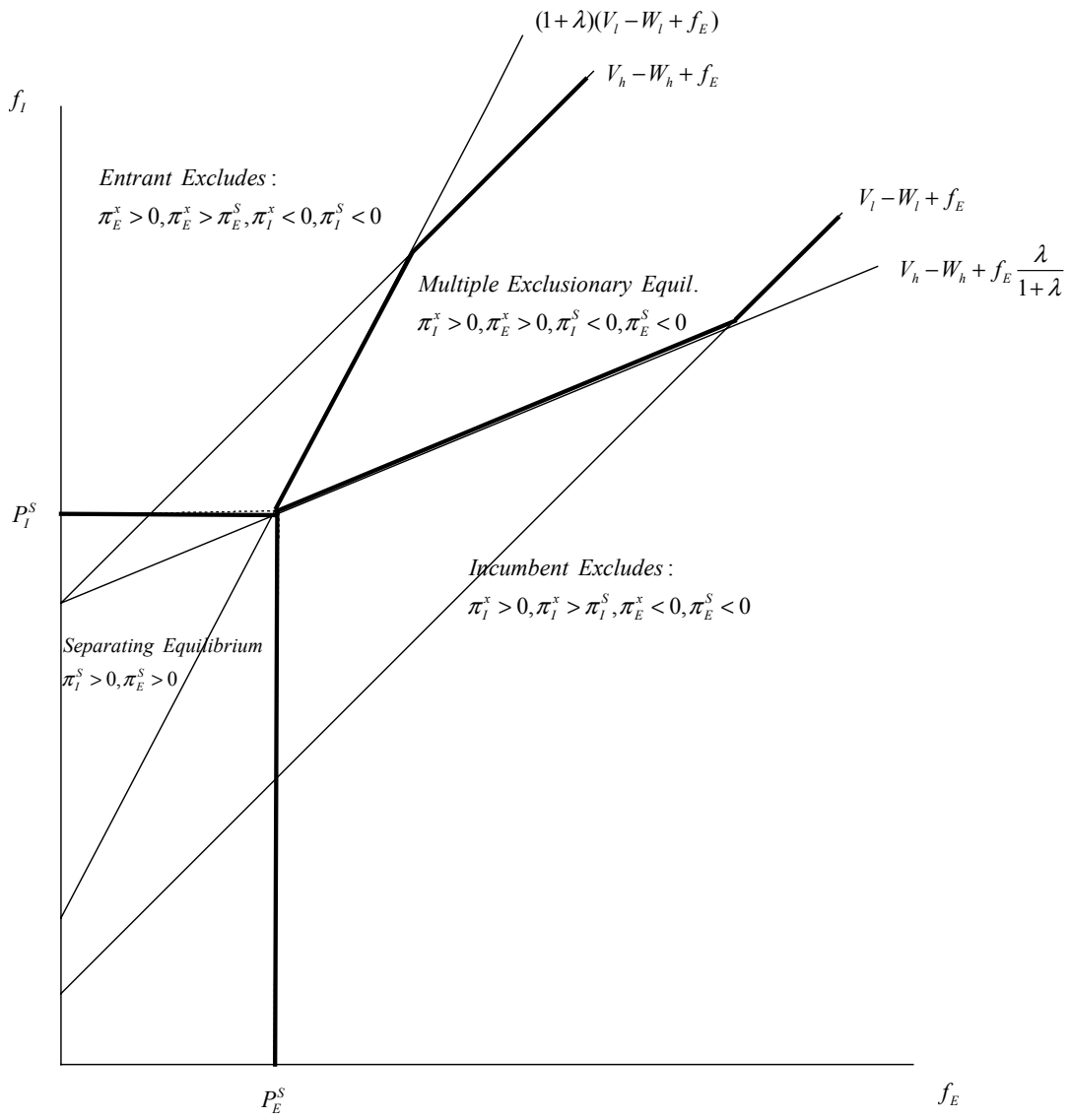


Figure 3
Equilibrium Market Structures

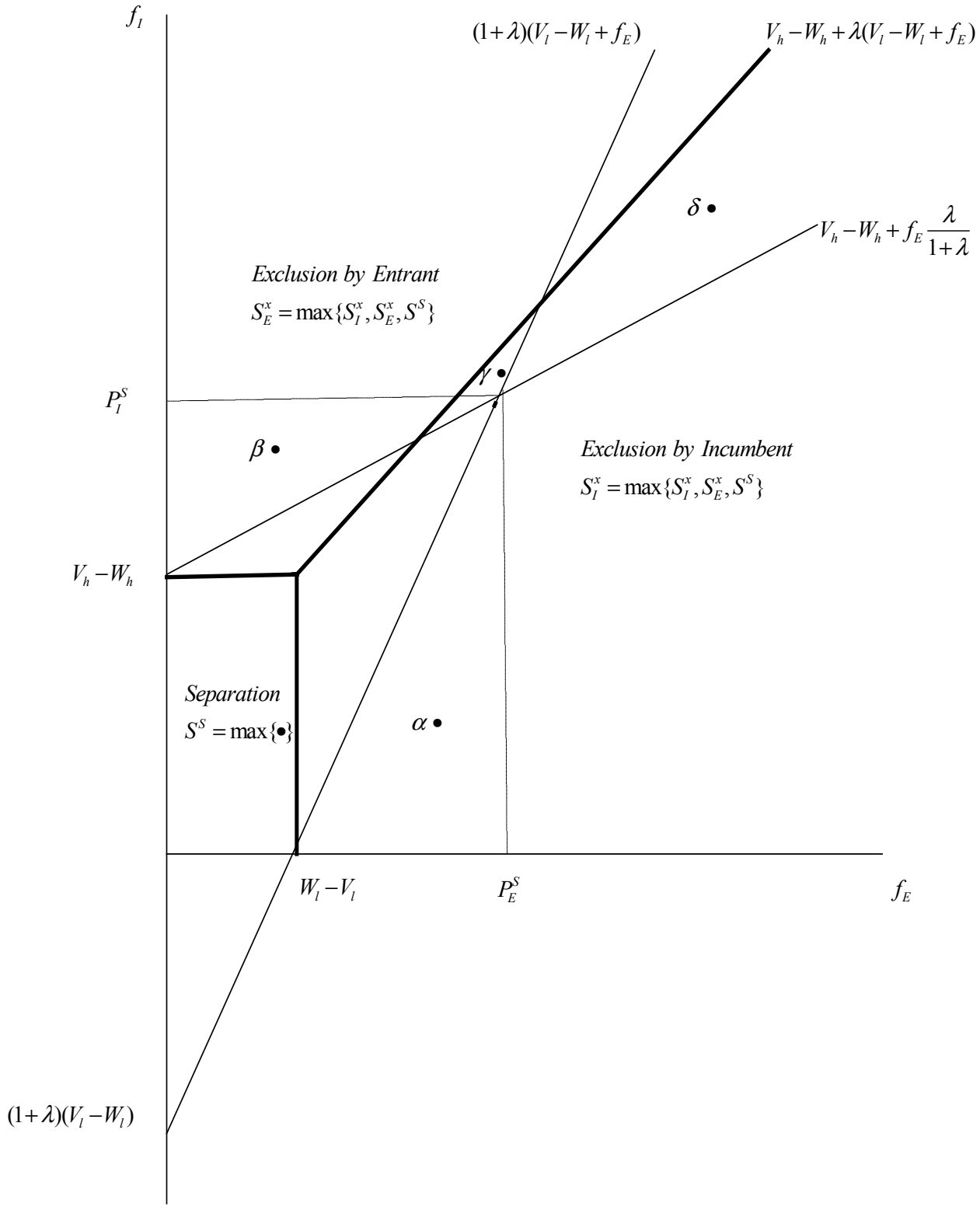


Figure 4
Boundaries for Efficient Market Structures

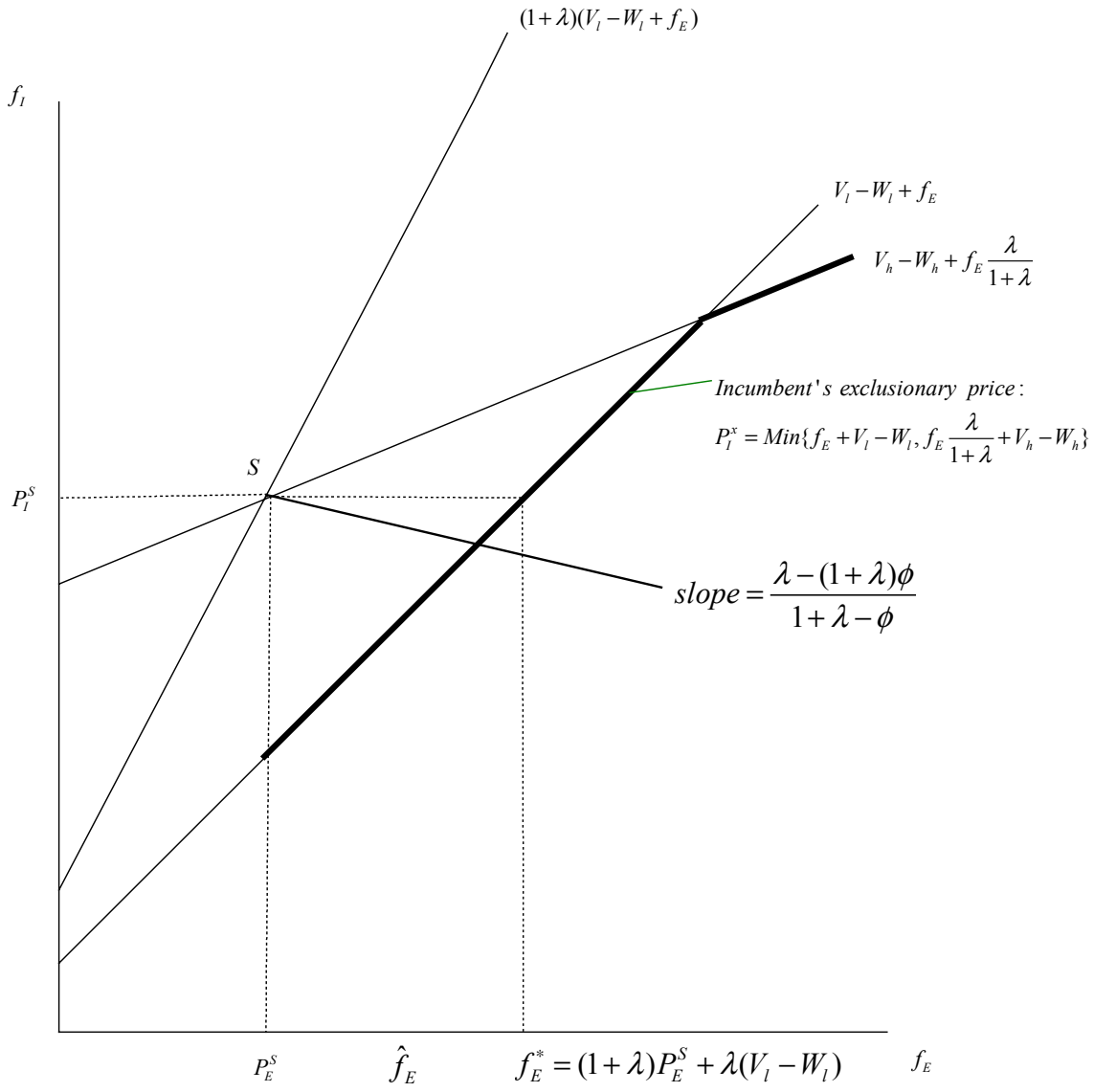
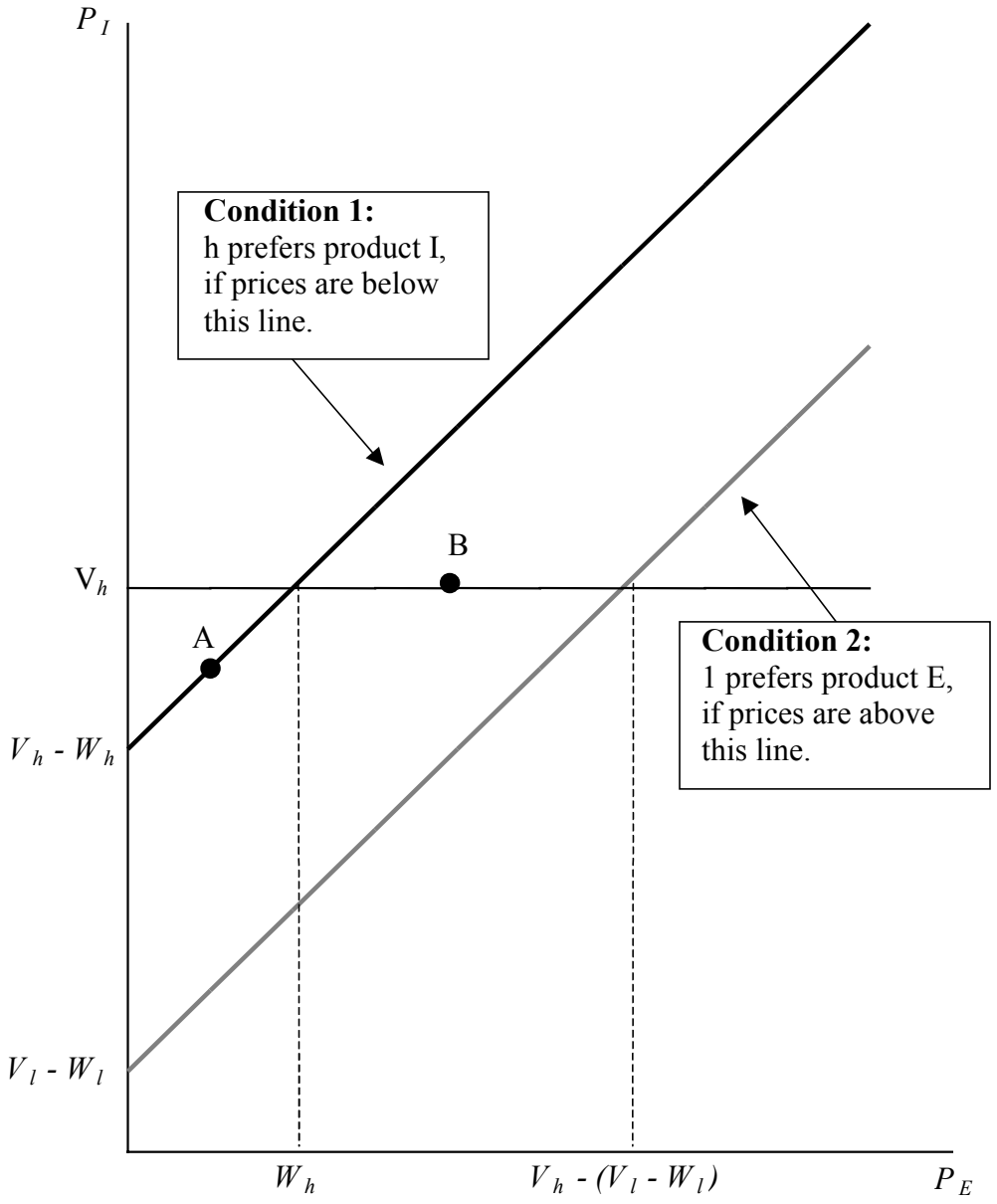


Figure 5
The Effects of Entry on the Incumbent's Price

Figure 6. The Opportunity Set for a Multi-Product Monopolist



Appendix on Multi-Product Monopoly

Proposition 12 (Multi-Product Monopoly): Consider a firm that cooperatively prices goods I and E. Without loss of generality, assume that product demand valuations satisfy (a) $V_h > V_l$ and (b) $V_h - W_h > V_l - W_l$. In addition, maintain the following regularity assumptions: (c) $V_h > W_h$, which insures that good E is not strictly superior to good I; (d) $\max\{F_I, F_E\} < N_h(V_h - W_h)$, which restricts the size of fixed operating costs; (e) $\max\{V_l, W_l\} > 0$, so that all consumers place a positive value on at least one good; and (f) maximal profits are positive. Given these assumptions, the following results characterized outcomes under multi-product monopoly.

A. **(Selling Regimes)**

1. The firm either segments the market, selling good I to type *h* and good E to type *l*, or it sells only good I.
2. $W_l \geq W_h$ is sufficient, but not necessary, for segmentation.
3. When the firm sells good I only, it sells to all consumers if $(1+\lambda)V_l > V_h$ and to type *h* only, otherwise.

B. **(Pricing and Consumer Surplus)**

1. When $W_l \geq W_h$, the firm prices at $P_I^M = V_h$ and $P_E^M = W_l$, and it extracts all consumer surplus.
2. When $W_l < W_h$, and the firm segments the market, it prices at $P_I^M = V_h + W_l - W_h$ and $P_E^M = W_l$. Consumer surplus equals $N_h(W_h - W_l)$.
3. When the firm sells good I only, it prices at $P_I^M = V_l$ if $(1+\lambda)V_l \geq V_h$ and $P_I^M = V_h$, otherwise. Consumer surplus equals $N_h(V_h - V_l)$ in the former case and zero in the latter case.

C. **(Allocative Efficiency)**

1. When the firm segments the market, the allocation of goods to consumers is efficient if $W_l \geq V_l$ and inefficient, otherwise.

2. When the firm sells good I to all consumers, the allocation of goods to consumers is efficient.
3. When the firm sells good I only to type *h* only, the allocation is inefficient.

D. **(Design Incentives)**

1. If (i) the allocation is efficient, or (ii) the firm does not segment the market, than any marginal design change that raises profit also raises total surplus. If neither (i) nor (ii) hold, then some profitable design changes raise total surplus and others lower it.
2. When consumer surplus is positive, some profitable design changes raise consumer surplus and others lower it.

Proof:

Parts A and B: If the firm segments the market, condition (b) implies that it sells I to *h* and E to *l*. If $W_l \geq W_h$ and the firm segments the market, it maximizes profit by pricing at the boundary point B in Figure 6, where $P_I^M = V_h$ and $P_E^M = W_l$. Since these prices extract all consumer surplus, the firm can do no better. Thus, $W_l \geq W_h$ is sufficient for segmentation with prices $P_I^M = V_h$ and $P_E^M = W_l$.

Next, consider the situation when $W_l < W_h$. If the firm segments the market, it prices at the boundary point A in Figure 6, where $P_I^M = V_h + W_l - W_h$ and $P_E^M = W_l$. In this case, consumer surplus equals $N_h\left(P_I^M - V_h\right) + N_l\left(P_E^M - W_l\right) = N_h\left(W_l - W_h\right)$. With segmentation (and optimal pricing), $\pi^M\left(Both\right) = N_h\left(V_h + W_l - W_h\right) + N_l W_l - F_I - F_E$. With sales of good I only, $\pi^M\left(I\right) = \max\left\{\left(N_h + N_l\right)V_l - F_I,\, N_h V_h - F_I\right\}$. With sales of good E only, $\pi^M\left(E\right) = \max\left\{\left(N_h + N_l\right)W_l - F_E,\, N_h W_h - F_E\right\}$. Using condition (c), these profit expressions imply that sales of good E to type-*h* only is dominated by selling good I to type-*h* only. Using condition (d), $\pi^M\left(Both\right)$ exceeds the profit from selling good E only to both types. Thus, selling good E only is dominated.

To show that segmentation may or may not maximize profits when $W_l < W_h$, use the profit expressions to compute outcomes in the following examples:

Example (i): Let $V_h = 100$, $V_l = 12$, $W_h = 10$, $W_l = 8$, $N_h = N_l = 1$ and $F_I = F_E = 0$. The profit-maximizing outcome involves segmentation with $P_I^M = 98$ and $P_E^M = 8$. Type *h* buys I, and type *l* buys E. This allocation of goods to consumers is inefficient, because good I is strictly superior to good E. Consumer surplus is 2, and profit is 106.

Example (ii): Same parameter values as in (i), except that $W_h = 50$. The profit-maximizing outcome involves sales of good I at price $P_I^M = 100$ to type *h* only. Good E is not sold. The allocation of goods to consumers is inefficient. Consumer surplus is 0, and profit is 100.

Examples (i) and (ii) establish that the multi-product monopolist may or may not segment the market when $W_l < W_h$, depending on other parameter values. Together with examples (i) and (ii), the next two examples can be used to show that all of the results stated in Proposition 12 are non-vacuous.

Example (iii): Same parameter values as in (i), except that $V_l = 60$. The profit-maximizing outcome involves sales of good I to both types at price $P_I^M = 60$. The allocation is efficient. Consumer surplus is 40, and profit is 120.

Example (iv): Same parameters as in (i), except that $W_l = 20$. The profit-maximizing outcome involves segmentation with prices $P_I^M = 100$ and $P_E^M = 20$. Type *h* buyer I, and type *l* buys E. The allocation of goods to consumers is efficient, because $V_h > W_h$ and $V_l < W_l$. Consumer surplus is zero, and profit is 120.

Putting the pieces together, the firm either segments the market, sells good I to type *h* only, or sells good I to both types. Using the expression for $\pi^M(I)$, a firm that sells good I only sells to all consumers if $(1+\lambda)V_l \geq V_h$ and to type h only, otherwise. The consumer surplus expressions when the firm sells good I only follow immediately.

Part C: (1) Making use of condition (c), the proof follows straightforwardly for the segmentation case. (2) If the firm sells I to all consumers, then $\pi^M(I) \geq \pi^M(Both) \Rightarrow (N_h + N_l)(V_l - W_l) \geq N_h(V_h - W_h) - F_E > 0 \Rightarrow V_l > W_l$, making use of condition (d). But, if $V_l > W_l$ and $V_h > W_h$ (condition (c)), then it is efficient to allocate good I to all consumers. (3) If the firm sells I only to *h* only, the allocation is inefficient

because type-l consumers place a positive value on at least one good (condition (e)). Examples (i)-(iv) above establish that these efficiency results are non-vacuous.

Part D: (1) By part C, an efficient allocation implies that $W_l \geq W_h$ or that the firm sells good I to all consumers. When $W_l \geq W_h$, part B.1 implies that profitable design improvements also raise total surplus. When the firm sells good I to all consumers part B.3 implies the same conclusion. By part A, if the firm does not segment the market, it sells good I only. When it sells good I only, part B.3 again implies the conclusion. The only remaining possibility involves segmentation with $W_l < W_h$. By part B.2, marginal increases in V_h and W_l raise both profits and total surplus in this case, whereas marginal increases in W_h lower profits and raise total surplus. (2) The result follows directly from parts B.2 and B.3.

Discussion:

Proposition 12 gives two simple conditions that suffice for an efficient allocation under multi-product monopoly. First, $W_l \geq \max\{V_l, W_h\}$ implies segmentation with an efficient allocation. Second, if $W_l < W_h$, the allocation is also efficient whenever the monopolist sells good I to both types. Hence, multi-product monopoly leads to efficient allocations for a large region in the space of design parameters.

Different market structures give rise to a misallocation of goods in different regions of the parameter space. Hence, it is not possible to uniformly rank alternative market structures – monopoly versus two competing firms – by the criterion of allocative efficiency or total surplus. More surprisingly, consumer surplus can be greater under monopoly than with two competing firms. As an example, consider the following parameters values: $V_h = 9$, $V_l = 5$, $N_h = N_l = 1$, $F_I = F_E = 0$, $W_h = 2$ and $W_l = 1.75$. Given these values, one can use Proposition 1 and the formulas in the proof to Proposition 12 to show that multi-market monopoly yields greater consumer (and total surplus) than the two-firm market structure.

Proposition 12 also says that product design incentives are often positively aligned with total surplus under multi-product monopoly. That is, the profit derivatives with respect to marginal design changes have the same sign pattern as the total surplus derivatives. The monopolist's marginal design incentives are always in the direction of

raising total surplus when the allocation is efficient, and sometimes when the allocation is inefficient.

When $W_l < W_h$, and the monopolist sells both goods, Part B.2 of the theorem implies that the monopolist has an incentive to lower W_h. Here, W_h is the value that type-*h* consumers ascribe to the good that they do not purchase. Lowering W_h allows the monopolist to raise the price on sales of good I to type-*h* consumers. This is the same effect that underlies adverse design incentives in the separating equilibrium with two firms. However, the effect is weaker under multi-product monopoly in two respects. First, the incentive for quality degradation arises in a smaller region of the parameter space under multi-product monopoly. Second, even in that region, the monopolist benefits from quality degradation in only one, not two, directions.

The case of innovation along a fixed path also involves less scope for adverse incentives under multi-market monopoly. To see this point, note again that the monopolist has no design degradation motive except under segmentation with $W_l < W_h$. Even in this case, part B.2 of Proposition 12 implies that innovation in good I is profitable for the monopolist for *any* value of $\Delta V_l / \Delta V_h$, in sharp contrast to the situation with two firms. Innovation in good E is profitable for the monopolist if $\Delta W_h / \Delta W_l < 1 + \lambda$, which is identical to the corresponding condition in Proposition 7.A that applies in the two-firm separating equilibrium.

In summary, adverse design incentives are less prevalent in the space of design parameters under multi-product monopoly than with two competing firms. Moreover, the multi-product monopolist has a motive for product degradation along at most one direction. In contrast, the two-firm market structure gives rise to motives for product degradation along two directions at any interior separating equilibrium.