INFORMATIONAL PRODUCT DIFFERENTIATION AS A BARRIER TO ENTRY*

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In a market for experience goods, the products of an incumbent firm and a new entrant are informationally differentiated. A signalling model is analyzed, and it is shown that informational product differentiation can be a barrier to entry (even under 'pro-entry' assumptions). Furthermore, when products are informationally differentiated, cost-based notions of predation are argued inappropriate.

1. Introduction

An experience good [Nelson (1970)] is a product whose quality becomes known to each consumer only after the good has been tried or experienced; its quality cannot be determined by inspection. For such goods, the products of an incumbent firm and an entering firm are informationally differentiated. Consumers may know the quality of the established product, but not that of the entrant's.

Bain (1956) initially argued that informational product differentiation can be a barrier to entry. This led to a tremendous amount of research, both in economics and marketing.[1] Of particular interest is Schmalensee (1982). In his model, an incumbent with a known high quality product competes with an entrant whose product quality is unknown (perhaps high, perhaps low). Schmalensee concludes that the incumbent may make profits without encouraging entry of an equally efficient, high quality entrant. In effect, consumers seek insurance and will pay a risk premium for a known product.

As von Weizäcker (1980) has argued, one definition of barriers to entry is obstacles to new competition which serve to preserve inefficiencies. From this

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[1]See, e.g., Conrad (1983), Dean (1969), Farrell (1986), Schmalensee (1979, 1982), Thomas (1985) and Yip (1982).

perspective, informational product differentiation is a barrier to entry when it leads to the threat of entry being insufficient to induce efficient pricing.[2]

In this paper, the Bain–Schmalensee thesis is extended in two important directions. The first involves the nature of the distortion. Bain and Schmalensee emphasized the ability of an entrant to eliminate price distortions when the actual quality of the entrant is identical to that of the incumbent. We consider quality distortions. Suppose an incumbent is known to have a low-quality product, while consumers are uncertain whether an entrant's quality is high or low. (The high quality product is assumed to generate more social surplus if it is purchased.) Then: Can the efficient (high-quality) entrant 'win' the market from the inefficient (low-quality) incumbent? We demonstrate that inefficiency in quality can persist in the presence of informational product differentiation: this form of differentiation is a barrier to entry.[3]

The second extension concerns consumers use of price as a signal of quality. Schmalensee's consumers ignore price in forming beliefs about quality. In contrast, we develop a signalling model in which consumers draw *rational* inferences about quality from prices. We show that signalling equilibria exist in which a low-quality, inefficient incumbent is able to permanently bar the entry of a high-quality, efficient entrant.

As the entrant's quality is commonly known to be at least as good as the incumbent's, it may seem surprising that the entrant has difficulty gaining market share. The intuition is roughly as follows. Consumers initially do not know entrant quality, and they therefore will try the entrant's product only if a 'reasonably' low price is charged. Assuming that high-quality products are more costly to produce, the introductory prices which attract consumers to the entrant may be below the cost of high-quality production. Thus, to win consumers, it may be necessary to initially experience losses.

High quality entry will occur only if these losses are no larger than the future profits coming to the entrant once consumers are induced to experience the quality of its product. The potential future profits are determined by the extent to which the total surplus from the high-quality product exceeds that for the low one. Thus, if this 'efficiency difference' is small, then the high-quality product may never be sold. When such an informational entry barrier occurs, the incumbent retains the market without pricing below marginal cost.

Finally, we note some related policy implications. For example, 'sales

[2]A similar definition is given by Bain (p. 3), who writes that barriers to entry can be assessed 'by the advantages of established sellers in an industry over potential entrant sellers, those advantages being reflected in the extent to which established sellers can persistently raise their prices above a competitive level without attracting new firms to enter the industry.'

[3]Indeed, a welfare-maximizing social planner would remove the incumbent in favor of the entrant, even if the planner were ignorant of the entrant's quality. Thus the 'market' outcome is inefficient to the 'planned' outcome, whether or not the planner knows entrant quality.

below cost' prohibitions or predation rules based upon marginal costs could enhance distortions created by this type of entry barrier.

We begin in section 2 with a discussion of the model's basic assumptions. To strengthen our results, we make 'pro-entry' assumptions. In section 3, we solve a static model. This model is then viewed as the second (and last) period of the general dynamic game, which is solved in section 4. Our goal in this paper is to give an explicit characterization of a simple model. A number of important, but difficult, extensions remain. Section 5 contains a discussion of these extensions and concludes.

2. Basic assumptions

We consider a product which is either high or low quality. Letting q index quality, we represent these as H and L. Quality can only be determined perfectly after consumption (experience).

The game proceeds as follows. Initially, there is an incumbent firm with a known low-quality product. Incumbent quality is unalterable. In period one, an entrant appears. 'Nature' determines (once and for all) the entrant's quality of product. It is commonly known that nature selects H with probability δ and L with the probability $(1-\delta)$. Only the entrant knows nature's actual choice. The entrant then competes with the incumbent in period one and also in the future, which we summarize with a second period.

Our results can be most easily developed in a market with a single consumer. In any period, the consumer chooses between buying one unit of the product or zero units. If he does buy, then he must buy the whole unit from one firm only. Letting P represent price, we assume that the consumer has the utility function $V(q,P)=U(q)-P$, where $U(\mathrm{H})>U(\mathrm{L})>0$. The utility of no purchase is indexed to zero, so we can define $U_r \equiv r\cdot U(\mathrm{H})+(1-r)\cdot U(\mathrm{L})$ as the consumer's reservation price when quality is high with probability r.

The entrant is assumed to be in no way disadvantaged by entry costs or scale economies. Firms have constant marginal (and average) costs with $c(\mathrm{H})$ and $c(\mathrm{L})$ being the respective marginal (and average) costs for high- and low-quality production. We assume $c(\mathrm{H})>c(\mathrm{L})>0$. The social surplus attributable to a product is $U(q)-c(q)$. The social surplus for a unit of a product is a function of quality type but not price. We assume that the high-quality product is relatively efficient and that both products generate positive surplus $(U(\mathrm{H})-c(\mathrm{H})>U(\mathrm{L})-c(\mathrm{L})>0)$.

These assumptions are decidedly 'pro-entry': Entry is free, returns to scale are constant, and the entrant's product is known to be at least as good as that of the incumbent. We next assume that the consumer maximizes instantaneous expected utility in each period. We are thereby ignoring the incentive that the consumer has to try the entrant's product *in order to* make more informed choices in the future. This assumption of a myopically rational consumer makes the exposition of the model much easier. We show in section 5 that the assumption is not central to our results.

Finally, it is important to assume that the incumbent and the consumer always have common beliefs about the entrant's quality type. If the incumbent had private information about the entrant's type, then the consumer could use the incumbent's price as one signal of the entrant's quality of product. This difficult problem is left for future work.[4]

3. The static model and its welfare properties

We first analyze a static model in which the incumbent's product quality is known and the entrant's product may be of uncertain quality. These static equilibria will be used for the second period of the dynamic game. The number two is thus subscribed to the sets and strategies below.

We consider two static games. In the first, only the entrant has information about its quality. In the second game, all information is commonly shared. Both games are of interest on their own terms; moreover, the solutions to these two games will be used in solving the dynamic game.

3.1. Incomplete information

In the following, it will be convenient to represent the incumbent as I, the entrant as E, and the high- (low-) quality entrant as $H(L)$. Now, consider a game in which I's quality of product is known to be low and E's quality of product is known only to E. Let r be the commonly known prior probability that E is H. That is, the consumer and I believe that E is H with probability r. For now we can think of r as the probability that 'nature' selects entrant quality, q, equal to H in the static game

Let $Q \equiv \{L, H\}$ be the entrant quality set with the element q. We define $P \equiv [0, \infty)$ as the set of possible prices for each firm. We can now define strategies and beliefs for the players. A strategy v_2 for the consumer is defined by a mapping v_2: $(0,1) \times P \times P \rightarrow$ {buy from I, buy from E, don't buy}. The domain of this function includes the consumer's initial belief (r) about E's quality type and the prices charged by I and E. Simplifying, we write $v_2(P_2^I, P_2^e)$ for the consumer's strategy, where P_2^I and P_2^e represent arbitrary prices which might be observed. The consumer also has a belief function. Let b_2: $(0,1) \times P \rightarrow [0,1]$ be the posterior belief which updates the

[4]Implicitly, we assume that the incumbent cannot buy the entrant's product and that the consumer communicates with the incumbent. Presumably, the entrant would be worse off if its type were known to the incumbent.

prior r with the observation of P_2^e. We will write $b_2(P_2^e)$ to denote this posterior probability that $\boldsymbol{E}$ is $\boldsymbol{H}$.

$\boldsymbol{I}$'s price strategy is a mapping P_2^I: $(0,1)\rightarrow \boldsymbol{P}$. That is, $\boldsymbol{I}$ chooses its price given its belief (r) about $\boldsymbol{E}$'s type. $\boldsymbol{I}$ and $\boldsymbol{E}$ are assumed to select price simultaneously. We use $P_2^I(\mathrm{L})$ to represent $\boldsymbol{I}$'s price strategy. It is common knowledge to all players that $\boldsymbol{I}$'s product is of low quality; L is included in the representation of $\boldsymbol{I}$'s strategy as a simple reminder. The price strategies of $\boldsymbol{H}$ and $\boldsymbol{L}$, respectively, are represented as $P_2^e(\mathrm{H})$ and $P_2^e(\mathrm{L})$. Entrant strategy thus maps from $(0,1)\times Q$ into $\boldsymbol{P}$.

We define $\pi_2^{\mathrm{H}}(P_2^I, P_2^e)$ to be the profit that $\boldsymbol{H}$ gets when it charges P_2^e and when I charges P_2^I ($v_2(P_2^I, P_2^e)$ is implicit in this definition). $\pi_2^{\mathrm{L}}(P_2^I, P_2^e)$ and $\pi_2^I(P_2^I, P_2^e)$ are defined analogously.

Within this setting, we look for sequential equilibria as defined by Kreps and Wilson (1982). For our static game, an assessment (that is, a combination of strategies and beliefs) forms such an equilibrium if each player's strategy maximizes his payoff, given the equilibrium strategies of other players and his beliefs, and if each player's beliefs are consistent with Bayes' rule for events which could occur under the equilibrium strategies (events 'on the equilibrium path'). Beliefs are unrestricted off the equilibrium path. The lack of restrictions placed on beliefs often generates a plethora of equilibria, as very extreme beliefs off the equilibrium path can be selected to force a variety of choices on the equilibrium path. A huge literature on 'refinement of equilibria' has thus evolved with the goal of erecting criteria for plausible disequilibrium beliefs.[5] Perhaps the most basic refinement is that beliefs should not place weight on dominated strategies. In our static game, this is equivalent to requiring $P_2^e(\mathrm{H})\geqq c(\mathrm{H})$, $P_2^e(\mathrm{L})\geqq c(\mathrm{L})$, and $P_2^I(\mathrm{L})\geqq c(\mathrm{L})$. We adopt this range restriction. In addition, we restrict attention to pure strategy equilibria. This is a popular restriction which is not refinement-based; rather, we focus on pure strategy equilibria because they are simple to characterize and understand.

Formally, if an assessment $\{v_2(P_2^I, P_2^e);\ b_2(P_2^e);\ P_2^e(\mathrm{H});\ P_2^e(\mathrm{L});\ P_2^I(\mathrm{L})\}$ is to be an equilibrium for the static game beginning with the prior $r\in(0,1)$, then it is necessary that

$$P_2^I(\mathrm{L})\in \underset{P_2^I}{\operatorname{argmax}}\ r\cdot\pi_2^I(P_2^I, P_2^e(\mathrm{H}))+(1-r)\cdot\pi_2^I(P_2^I, P_2^e(\mathrm{L})). \tag{N1}$$

$$P_2^e(\mathrm{H})\in \underset{P_2^e}{\operatorname{argmax}}\ \pi_2^{\mathrm{H}}(P_2^I(\mathrm{L}), P_2^e) \tag{N2}$$

$$P_2^e(\mathrm{L})\in \underset{P_2^e}{\operatorname{argmax}}\ \pi_2^{\mathrm{L}}(P_2^I(\mathrm{L}), P_2^e). \tag{N3}$$

[5]See Cho and Kreps (1987) and Milgrom and Roberts (1986).

That is, each firm's price strategy must maximize its profits, given the equilibrium strategies of the other players and the firm's information.

It is also necessary that the consumer maximize expected utility, given his beliefs. $V(\mathrm{L}, P_2^I)$, $b_2(P_2^e) \cdot V(\mathrm{H}, P_2^e) + (1 - b_2(P_2^e)) \cdot V(\mathrm{L}, P_2^e)$, and 0 are, respectively, the expected utilities of buying from *I*, buying from *E*, and not buying. Thus, we have a fourth necessary condition for an equilibrium:

(*N4*) For any (P_2^I, P_2^e), the consumer picks an action corresponding to a maximum of the set $[V(\mathrm{L}, P_2^I), b_2(P_2^e) \cdot V(\mathrm{H}, P_2^e) + (1 - b_2(P_2^e)) \cdot V(\mathrm{L}, P_2^e), 0]$.

Note that the behavior of an indifferent consumer is not restricted. Finally, we must say something about beliefs.

(*N5*) The following two conditions must hold:
1. If $P_2^e(\mathrm{H}) \neq P_2^e(\mathrm{L})$, then $b_2(P_2^e(\mathrm{H})) = 1$ and $b_2(P_2^e(\mathrm{L})) = 0$.
2. If $P_2^e(\mathrm{H}) = P_2^e(\mathrm{L})$, then $b_2(P_2^e(\mathrm{H})) = r$.

N5 requires beliefs to agree with Bayes' rule along the equilibrium path. If *separation* (N5.1.) occurs price perfectly signals type, whereas if *pooling* occurs (N5.2.) price provides no information about type.

We can now define an *equilibrium for the static game* beginning with the prior $r \in (0, 1)$ as an assessment $\{v_2(P_2^I, P_2^e);\ b_2(P_2^e);\ P_2^e(\mathrm{H});\ P_2^e(\mathrm{L});\ P_2^I(\mathrm{L})]\}$ satisfying N1–N5.

In the proposition below, we will say that a firm *wins* (*loses*) *the market* if the consumer buys (does not buy) from the firm. This definition is clear when the firm is ***H*** or ***L***. When we day that ***I*** wins (loses) the market, we mean that the consumer buys (does not buy) from ***I***, whether ***E*** is ***H*** or ***L***.

Proposition 1. Consider the static, incomplete information game with $r \in (0, 1)$.
1. *Separating static equilibria exist and, in any such equilibrium,* $P_2^I(\mathrm{L}) = c(\mathrm{L}) = P_2^e(\mathrm{L})$, $P_2^e(\mathrm{H}) = U(\mathrm{H}) - U(\mathrm{L}) + c(\mathrm{L})$, ***H*** *loses the market, and* ***L*** *may or may not win the market.*
2. *If* $U_r - c(\mathrm{H}) \geqq U(\mathrm{L}) - c(\mathrm{L})$, *then there exist pooling static equilibria in which* ***I***:
   (*a*) *wins the market; this class of equilibria is characterized by* $P_2^I(\mathrm{L}) = c(\mathrm{L})$, $P_2^e(\mathrm{H}) = P_2^e(\mathrm{L}) = U_r - U(\mathrm{L}) + c(\mathrm{L})$.
   (*b*) *loses the market; this class of equilibria is characterized by* $c(\mathrm{L}) \leqq P_2^I(\mathrm{L}) \leqq P_2^e(\mathrm{H})$, $c(\mathrm{H}) \leqq P_2^e(\mathrm{H}) \leqq U_r - U(\mathrm{L}) + c(\mathrm{L})$, *and* $P_2^e(\mathrm{H}) = P_2^e(\mathrm{L})$.
3. *If* $U(\mathrm{L}) - c(\mathrm{L}) > U_r - c(\mathrm{H})$, *then pooling static equilibria do not exist.*

This completely characterizes the static equilibria for the incomplete information game: a formal proof is in Appendix 1.

In thinking about this proposition, notice first that ***H*** can't separate and win the market. Intuitively, for ***H*** to separate and win, ***L*** must choose not to mimic *H*'s price. This in turn requires *H* to price below $c(\mathrm{L})$. But *H* is clearly unwilling to win the market at such a price in a static game. Thus, in any static separating equilibrium, an informational barrier to entry exists. Note that separating equilibria always exist, and that only separating equilibria exist when $U(\mathrm{L})-c(\mathrm{L})>U_r-c(\mathrm{H})$.

So, if *H* is to win the market, then *E* must pool. Proposition 1 indicates that $U_r-c(H)\geqq U(\mathrm{L})-c(\mathrm{L})$ is also necessary for *H* to win the market. The argument is intuitive. Since a pooling *E* gives higher expected quality than does *I*, *E* can pool at a premium above *I*'s price. But, since prices below $c(\mathrm{H})$ are dominated for *H*, *E* cannot credibly pool at prices below $c(\mathrm{H})$. As *I* will price as low as $c(\mathrm{L})$ in order to save its market, it follows that *E* can pool and win only if the premium *E* can charge above $c(\mathrm{L})$ is sufficiently large to enable *E* to price above $c(\mathrm{H})$. This premium is measured by $U_r-U(\mathrm{L})$. Thus a pooling *E* can win the market only if $U_r-U(\mathrm{L})+c(\mathrm{L})\geqq c(\mathrm{H})$. Notice that this condition is necessary but not sufficient, for a pooling *E* to win. A more rigorous and complete description is provided in Appendix 1.

Since *H* can displace *I* in the static game only if $U_r-c(\mathrm{H})\geqq U(\mathrm{L})-c(\mathrm{L})$, it is important to ask what economic factors might cause this inequality to be met. Note first that the inequality is more likely to hold the greater the chance that *E* is *H* (i.e., the higher is r). Firms with high-quality reputations in other markets might thus face less of an informational entry barrier. The inequality is also more likely to be met the greater is $U(\mathrm{H})-c(\mathrm{H})-U(\mathrm{L})+c(\mathrm{L})$. Thus, if the high-quality product is 'very' efficient relative to the low-quality product, then *H* has a greater chance of displacing *I*.

The static model with incomplete information often generates the inefficient outcome in which *H* is unable to usurp *I*.[6] In the next section, we see that giving *H* an extra period with which to work often (but not always) enables it to displace *I*. Before pursuing the dynamic model, however, we must first consider the static, full information model.

3.2. Full information

Suppose all products are of known quality. Our static equilibrium concept is then simply a Nash equilibrium in prices (viz. N1 − N4 with $r=0$ or 1 and $b_2(P_2^e)\equiv r$). Proposition 2 tells us the obvious: if firms play a static, full information game, then efficiency obtains.

Proposition 2. Consider the static, full information game.

[6]In the static game, *L*'s profit always exceeds (or equals) *H*'s profit in equilibrium. Thus, if quality were a choice variable, it would be difficult to motivate the high quality selection. In the dynamic model, however, *H* may earn more than *L*, so that a once and for all high quality choice is a possibility. One can then imagine *E* choosing quality after observing an imperfect signal as to whether parameters will be such that high quality is more profitable than low. δ would represent the probability of a signal realization leading to the high quality choice.

1. *If* $q=\mathrm{H}$, *then the unique static equilibrium has* $P_2^I(\mathrm{L})=c(\mathrm{L})$, $P_2^e(\mathrm{H})=U(\mathrm{H})-U(\mathrm{L})+c(\mathrm{L})$. *and,* ***H*** *winning the market.*
2. *If* $q=\mathrm{L}$, *then in any static equilibrium,* $P_2^I(\mathrm{L})=c(\mathrm{L})\doteq P_2^e(\mathrm{L})$. ***L*** *may or may not win the market.*

Proof of Proposition 2 is direct.

4. The dynamic model and its welfare properties

We now analyze a dynamic model which begins in the first period, with the second period corresponding to the static games above. For clarity, we call a sequential equilibrium for the dynamic game a dynamic equilibrium. We begin with an informal definition of a dynamic equilibrium.

It will first be useful to define first period posterior beliefs $b_1(P_1^e)$. At the start of the first period, the consumer and I believe that E is H with probability δ, the probability that nature chooses high quality. E and I then simultaneously choose their first period prices (P_1^e and P_1^I, respectively). The consumer observes first period prices and revises his beliefs. $b_1(P_1^e)$ is this revised belief; after observing P_1^e, the consumer believes that E is H with probability $b_1(P_1^e)$.

Now focus on the second period. Three states are possible. If E's product is tried in period one, then all players are fully informed in the second period and Proposition 2 will characterize second period play. Next, it may be that E's product is not experienced in the first period and the consumer and I conclude the period with the belief $b_1(P_1^e)\in(0,1)$. Taking this probability to be a sufficient statistic for period one play,[7] we can think of the second period as a static game of incomplete information with $r=b_1(P_1^e)$ and Proposition 1 will characterize second period behavior. Finally, it may be that E's product is not tried in period one and the consumer and I are certain in their beliefs, $b_1(P_1^e)\in\{0,1\}$. The corresponding static game is a degenerate game of incomplete information. Cramton (1985) and Rubinstein (1985) suggest a natural requirement may be that second period beliefs be 'passive' to new information: $b_2(P_2^e)\equiv 1(0)$ when $r=1(0)$. For our game, we find this to be reasonably persuasive and use the restrictions implied by a passive belief structure to characterize second period play when $b_1(P_1^e)=r\in\{0,1\}$.

We turn next to the first period. Strategies $\{v_1(P_1^I,P_1^e),\ P_1^e(\mathrm{H}),\ P_1^e(\mathrm{L}),\ P_1^I(\mathrm{L})\}$ can be described as they were for the second period game. Since the consumer maximizes instantaneous expected utility, the dynamic equilibrium conditions for $v_1(P_1^I,P_1^e)$ are like those developed earlier for $v_2(P_2^I,P_2^e)$. Similarly, the belief $b_1(P_1^e)$ must obey Bayes' rule on the equilibrium path.

First period prices determine whether the consumer experiences the entrant's product (and hence beliefs). Consequently, in addition to affecting

[7]Thus we are using a 'Markov' refinement of equilibria.

first period profits, they influence the state with which the second period begins and thereby second period profits. Thus, the first period pricing strategies, $P_1^I(\mathrm{L})$, $P_1^e(\mathrm{H})$, and $P_1^e(\mathrm{L})$, are selected to maximize the expected value of the sum of first period profit plus discounted second period profits, given equilibrium strategies of all other players. Prices are selected simultaneously so I chooses $P_1^I(\mathrm{L})$ knowing that $P_1^e(\mathrm{H})((P_1^e(\mathrm{L}))$ will be simultaneously picked with probability $\delta(1-\delta)$.

In the below we refer to a separating (pooling) dynamic equilibrium as one in which $P_1^e(\mathrm{H}) \neq P_1^e(\mathrm{L})(P_1^e(H) = P_1^e(\mathrm{L}))$.[8] We come now to our first proposition for the dynamic game.

Proposition 3. There exists no separating dynamic equilibrium.

The proof of this proposition is in Appendix 2. Intuitively, if a separating equilibrium were to exist, then all information would be revealed, and so I and L would find themselves in a very competitive relationship. In fact, $P_1^e(\mathrm{L}) = P_1^I(\mathrm{L}) = c(\mathrm{L})$ (the usual Bertrand solution) would be necessary, and I and L would make zero game profit. Thus, if H is to separate and win the first period market, $P_1^e(\mathrm{H}) < c(\mathrm{L})$ is needed, lest L mimic H. But, since $P_1^I(\mathrm{L}) = c(\mathrm{L})$, there is no reason for H to price below $c(\mathrm{L})$ – a slight price raise, even if thought to signal low quality, would still attract the consumer. Hence, H cannot separate with a price below $c(\mathrm{L})$, since there always exists a slightly higher price that gives more profit.[9] Further, it cannot be that H separates and loses the first period market, since L could mimic H's price in period one, enter period two *believed* to be H, and make period two profits. Separating dynamic equilibria are thus impossible.

In light of Proposition 3, we need look only for pooling equilibria. The following assumption (discussed below) is important to the next proposition.

$$A\colon (c(\mathrm{L}) - c(\mathrm{H})) + \alpha \cdot (U(\mathrm{H}) - U(\mathrm{L}) + c(\mathrm{L}) - c(\mathrm{H})) > \max[0, \alpha \cdot (U_\delta - U(\mathrm{L}) + c(\mathrm{L}) - c(\mathrm{H}))],$$

where $\alpha \in (0,1)$ is the discount factor.

Proposition 4. Suppose that A holds. Then in any dynamic equilibrium, E wins the first period market, and the prices supporting such equilibria are characterized by $P_1^I(\mathrm{L}) \leqq P_1^e(\mathrm{H})$, $c(\mathrm{L}) \leqq P_1^e(\mathrm{H}) \leqq U_\delta - U(\mathrm{L}) + \min(c(\mathrm{L}), P_1^I(\mathrm{L}))$, *and* $P_1^e(\mathrm{H}) = P_1^e(\mathrm{L})$.

[8]Note this definition refers only to separating or pooling in the first period. This is a useful means of organizaing the theorems below.

[9]An alternative assumption is that the set of possible prices is finite, in which case a separating equilibrium with $P_1^I(\mathrm{L}) = c(\mathrm{L}) = P_1^e(\mathrm{L})$ and $P_1^e(\mathrm{H}) = a$, where a is the largest price less than $c(\mathrm{L})$, might exist. The existence of this equilibrium would not affect the qualitative results of the paper. Notice, in particular, that $a < c(\mathrm{H})$ and that the separating equilibrium does not exist when P^* (defined below) is no less than $c(\mathrm{L})$.

We note first that E always wins the first period market when A holds. Thus, if E is H, then I is displaced in period one and so I is also displaced in period two. When A holds, inefficiency does not persist, and the informational entry barrier is not effective. Note that A is more likely to hold the larger $U(\mathrm{H})-c(\mathrm{H})$ is relative to $U(\mathrm{L})-c(\mathrm{L})$. A 'very' efficient entrant always overcomes informational disadvantages.

A formal proof that E wins the first period market under A is not difficult. Suppose to the contrary that a dynamic equilibrium exists in which E loses the initial market. What is the maximum profit that H could make in such an equilibrium? By assumption, H makes zero first period profit. Since first period prices are pooled, H enters period two with a product believed to be high quality with probability δ. Using Proposition 1 (with $r=\delta$), we see that H can at most make $\max[0, \alpha\cdot(U_\delta-U(\mathrm{L})+c(\mathrm{L})-c(\mathrm{H}))]$ discounted profit in an equilibrium of the described type. Notice also from Proposition 1 that I makes zero second period profit when E enters period two with $r=\delta$. Since I wins the first period market, it must therefore be that $P_1^I(\mathrm{L})\geqq c(\mathrm{L})$. The contradiction is now immediate. By charging a first period price of $c(\mathrm{L})$ (perhaps less ε), H could win the initial market, even if it were initially thought to be L. H could then enter period two with a product of known quality and make a second period profit of $U(\mathrm{H})-U(\mathrm{L})+c(\mathrm{L})-c(\mathrm{H})$ (by Proposition 2). Under assumption A, H would undertake this deviation, thus destroying the putative pooling equilibrium. The point is that a 'very' efficient entrant is willing to undercut I, if such behavior is needed to win the initial market.

Thus, when A holds it must be that pooling occurs in period one and E wins the first period market. In Proposition 4, it is also claimed that $P_1^e(\mathrm{H})=P_1^e(\mathrm{L})\leqq U_\delta-U(\mathrm{L})+c(\mathrm{L})$ is necessary for equilibrium when A holds. The argument is intuitive. From Proposition 2, I makes zero game profit when E wins the first period market. Thus, if E pooled its first period price at $P_1^e(\mathrm{H})>U_\delta-U(\mathrm{L})+c(\mathrm{L})$, then I would deviate to win the initial market with the price $U(\mathrm{L})-U_\delta+P_1^e(\mathrm{H})$ (perhaps less ε). But we know E must pool and win the first period market. It must therefore be that $P_1^e(\mathrm{H})=P_1^e(\mathrm{L})\leqq U_\delta-U(\mathrm{L})+c(\mathrm{L})$. The remainder of the proof to Proposition 4 is given in Appendix 2, where the prices described are shown to be necessary and sufficient for equilibrium.

Notice that E's first period price may be as low as $c(\mathrm{L})$. H may be therefore required to initially price below $c(\mathrm{H})$ in order to remove the inefficient incumbent. That is, efficient entry may come with an introductory price below marginal cost. Furthermore, if $U_\delta-U(\mathrm{L})+c(\mathrm{L})<c(\mathrm{H})$ and A holds, then in *any* equilibrium, H displaces I and H introduces its product at a price below marginal cost. In short, an 'unexpected' (small δ) but 'very' efficient (A holds) product always wins the market from the inefficient incumbent, and it always does so with an introductory offer that is below marginal cost.

The behavior of H might, on the surface, appear predatory. After all, H comes into the market, prices below cost, wins the entire market from I, and then raises price.[10] But H's low introductory price is really an investment in information diffusion (i.e., a form of insurance for the consumer), which would be observed, to some extent, even if there were no incumbent. Thus, as Demsetz (1982) has argued, prohibitions on pricing below current costs are inappropriate for young firms in experience goods markets. Indeed, if H is 'unexpected' and 'very' efficient, then in *any* equilibrium, successful and efficient entry only occurs via below-cost pricing.

What happens when A fails? Then H can no longer assure itself of winning the market with the threat of undercutting I, for this threat is no longer credible. This means that distinctly new equilibria may appear. The next proposition shows that if A fails then there exists a dynamic equilibrium in which I wins the market in both periods and inefficiency persists because of informational product differentiation. Furthermore, I wins the market without pricing below cost.

Before stating Proposition 5, it is convenient to define P^* by $P^* - c(\mathrm{H}) + \alpha \cdot (U(\mathrm{H}) - U(\mathrm{L}) + c(\mathrm{L}) - c(\mathrm{H})) \equiv 0$. Thus, if $P^* \geqq c(\mathrm{L})$, then A fails. P^* is clearly the lowest period one price which H would be willing to charge *if* H expected to win the first (and second) period market. Prices below P^* are not necessarily dominated for H, however, since H could profit with such a price if it lost the initial market but induced beliefs (gained a reputation) consistent with the winning of the period two market.

Proposition 5. Suppose $P^* \geqq c(\mathrm{L})$. *Then there exists a dynamic equilibrium in which* I *wins the market in both the first and second periods. In this equilibrium,* $P_1^I(\mathrm{L}) = c(\mathrm{L})$ *and* $P_1^e(\mathrm{H}) = P_1^e(\mathrm{L}) = U_\delta - U(\mathrm{L}) + c(\mathrm{L})$.[11]

In words, if H is relatively efficient, but not 'very' efficient, then it may be that H never wins the market. The guiding intuition is straightforward. Suppose the consumer believes that low, aggressive prices signal low quality. Then if H is to win the initial market, it must actually undercut I's price. When $P^* \geqq c(\mathrm{L})$, I can pick its price low enough that the initial cost to H of establishing its quality (viz, pricing below $P_1^I(\mathrm{L})$) exceeds the future benefits of having known high quality.

[10]The concept of a predatory entrant is not foreign to the courts. See, e.g., Buffalo Courier-Express v. Buffalo Evening News.

[11]H's first period price, $P_1^e(\mathrm{H}) = U_\delta - U(\mathrm{L}) + c(\mathrm{L})$, is quite plausible if it is no less than P^*, since $P_1^e(\mathrm{H})$ is then consistent with the possibility that the consumer might 'tremble' and buy from E. If instead $P_1^e(\mathrm{H}) < P^*$, then H will make negative game profits if it wins the initial market and will never make positive *equilibrium* profits if it loses this market. (The latter conclusion follows from $P^* < c(\mathrm{H})$ and Proposition 1.) Thus, while $P_1^e(\mathrm{H}) < P^*$ is not dominated, it is a somewhat unattractive price. Nevertheless, such a price may be required for existence of equilibrium under certain parameters (see note 14).

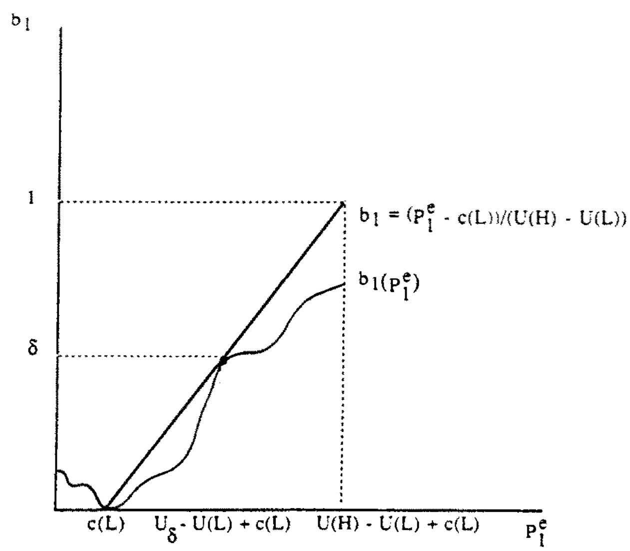

Fig. 1. A possible belief function.

The formal proof goes as follows. Specify as the static equilibrium (for any r) the separating equilibrium described in Proposition 1, with I winning the market. Choose beliefs such that $b_1(U_\delta - U(\mathrm{L}) + c(\mathrm{L})) = \delta$ and, for all $P_1^e > c(\mathrm{L})$, $b_1(P_1^e) \leqq (P_1^e - c(\mathrm{L}))/(U(\mathrm{H}) - U(\mathrm{L}))$. Allow any beliefs for entrant prices at or below $c(\mathrm{L})$. As shown in fig. 1, a wide range of possible beliefs are allowed under this formulation. In particular, the consumer is allowed to associate higher prices with higher posteriors (i.e., b_1 can be an increasing function).

To prove that the dynamic equilibrium in Proposition 5 exists, we note first that the described beliefs are Bayes-consistent with E's equilibrium strategy. We thus need only show that no player has incentive to deviate in period one. Given the consumer's beliefs, he is indifferent between buying from E at $U_\delta - U(\mathrm{L}) + c(\mathrm{L})$ and buying from I at $c(\mathrm{L})$. Thus, an optimal response is to buy from I. (Such indifference is necessary for an equilibrium in which I wins the market. If the consumer strictly preferred I to the pooling E, then I would raise its price until the consumer became indifferent.)[12] Consider next I. There is clearly no reason for I to deviate. $P_1^I(\mathrm{L}) < c(\mathrm{L})$ causes negative game profit and $P_1^I(\mathrm{L}) > c(\mathrm{L})$ causes the market to be lost and zero game profit to be made.

The more interesting players are H and L. Given the above belief

[12]With a finite grid of prices, indifference is not necessary. The consumer can strictly prefer to buy from I, and yet I will not raise price since the 'next price up' would cause the consumer to go to E.

structure, a deviant price above $c(\mathrm{L})$ will not attract the consumer. Thus, such a price generates zero first period profits and no second period profit. Consider then deviant prices at or below $c(\mathrm{L})$. $\boldsymbol{L}$ makes zero second period profit when its type is known, so $\boldsymbol{L}$ has no incentive to charge $c(\mathrm{L})$ or less. Since $P^* \geqq c(\mathrm{L})$, $\boldsymbol{H}$ will not price at or below $c(\mathrm{L})$ in order to attract second period business. Thus, neither $\boldsymbol{H}$ nor $\boldsymbol{L}$ has incentive to deviate, and Proposition 5 is proved.

Proposition 5 shows that an equilibrium exists in which efficient entry is permanently barred. If, however, $U_\delta - U(\mathrm{L}) + c(\mathrm{L}) \geqq P^*$, then it is easily shown that there also exist equilibria in which $\boldsymbol{E}$ wins both markets, making prediction difficult. We simply note here that both classes of equilibria are consistent with a wide range of beliefs and robust to the 'intuitive criterion' of Cho and Kreps (1987).[13] The equilibrium described in Proposition 5 is one plausible outcome.

A stronger case can be made if $P^* > U_\delta - U(\mathrm{L}) + c(\mathrm{L})$, as the following proposition states.

Proposition 6. *Suppose* $P^* > U_\delta - U(\mathrm{L}) + c(\mathrm{L})$. *Then in any dynamic equilibrium,* $\boldsymbol{I}$ *wins the first period market and* $\boldsymbol{H}$ *loses the market in both the first and second periods.*

The proof is direct. If $\boldsymbol{I}$ were to lose the initial market, then $\boldsymbol{I}$ would make zero game profits. Hence, $U_\delta - P_1^e(\mathrm{H}) \geqq U(\mathrm{L}) - c(\mathrm{L})$ would be required or $\boldsymbol{I}$ would choose to profitably win the first period market. But then $P_1^e(\mathrm{H}) < P^*$ and, by winning the first period market, $\boldsymbol{H}$ must make negative game profits. It must be that $\boldsymbol{I}$ wins the initial market. Next, since $c(\mathrm{H}) > P^*$, it follows that $U(\mathrm{L}) - c(\mathrm{L}) > U_\delta - c(\mathrm{H})$. Since $\boldsymbol{E}$ must pool in the initial period, Proposition 1 (with $r = \delta$) indicates that $\boldsymbol{H}$ must also lose the second period market.[14]

Put differently, if $\boldsymbol{H}$ is 'unexpected' and not 'very' efficient, then in *any* dynamic equilibrium an informational barrier permanently inhibits efficient entry.

5. Extensions, qualifications, and summary

We have presented a well-defined game with rational consumer behavior

[13]The Cho–Kreps intuitive criterion would eliminate an equilibrium if a disequilibrium period one price existed which would enable $\boldsymbol{H}$ but not $\boldsymbol{L}$ to earn more than in equilibrium, if upon choosing the price $\boldsymbol{E}$ were believed to be $\boldsymbol{H}$. The criterion has little force in our model, since quantity is fixed and so both entrants types always prefer higher 'winning' prices. A strengthened version of the criterion does appear to eliminate all separating equilibria other than that described in footnote 9, when the price space is finite.

[14]From Proposition 5, we know that equilibria of the type described in Proposition 6 exist. It is easily shown that $P^* > U_\delta - U(\mathrm{L}) + c(\mathrm{L})$ implies that in any dynamic equilibrium $P_1^e(\mathrm{H}) = P_1^e(\mathrm{L}) = U_\delta - U(\mathrm{L}) + c(\mathrm{L})$, $P_1^I(\mathrm{L}) = c(\mathrm{L})$, and the separating static equilibrium is played in period two. Thus, existence of equilibrium requires $P_1^e(\mathrm{H}) < P^*$ when $P^* > U_\delta - U(\mathrm{L}) + c(\mathrm{L})$.

in which a high-quality, socially efficient entrant is disadvantaged by the possibility that it might be a low-quality entrant. Two basic results were found. First, when informational product differentiation is present, below cost pricing may be required for a socially efficient outcome. Second, its presence may generate an entry barrier that prohibits entry of socially efficient firms.

The model is extremely simple, and it is important to consider the relaxation of its assumptions. To see that assumption of a myopically rational consumer is without loss of generality, consider the second period utility coming to the consumer in a dynamic equilibrium. From Proposition 2, the consumer gets utility $U(\mathrm{L})-c(\mathrm{L})$ in period two if he tries the entrant's product in period one. The other equilibrium possibility is that pooling occurs in period one and the consumer does not try the entrant's product. In this event, Proposition 1 indicates expected utility is again $U(\mathrm{L})-c(\mathrm{L})$ in period two, if $U_{\delta}-c(\mathrm{H})<U(\mathrm{L})-c(\mathrm{L})$. Thus, when this inequality holds the myopic rationality rule is implied by full rationality. Finally, if $U_{\delta}-c(\mathrm{H})\geqq U(\mathrm{L})-c(\mathrm{L})$, Proposition 1 tells us that the consumer can expect at least $U(\mathrm{L})-c(\mathrm{L})$ utility in period two, if he doesn't buy from the entrant in period one. The possibility of greater than $U(\mathrm{L})-c(\mathrm{L})$ utility emerges, since a consumer uninformed of entrant quality can 'force' a low second period entrant price by 'threatening' to believe that quality is low if a higher price is charged. This 'power-through-ignorance' effect can only make a myopically rational consumer *more* inclined to try the entrant's product in period one than would be a consumer with foresight. Given our orientation toward 'pro-entry' assumptions, the myopic rationality assumption thus can be regarded as an expositional aid made without loss of generality.

The assumption of a single consumer is more difficult to relax. The most natural model would allow for heterogeneous consumers and imperfect 'word-of-mouth' communication. This extension is certainly not trivial, as the entrant will eventually have two pieces of private information – its quality type and its information as to the number of consumers who know quality – and an uninformed consumer must guess the latter in order to use price to infer the former. Bagwell and Riordan (1988) have investigated a model of this sort for the monopoly case, but there appears to be no model of entry barriers and competition for such a market. The likely prediction is that better communication behooves the high-quality entrant. By assuming a single consumer, the present model sidesteps these important but difficult issues.[15]

[15]The single consumer model analyzed above corresponds closely with a multi-consumer, perfect communication model, since in either setting the purchase by any one consumer can determine the future information state of all consumers. The correspondence is not exact, however, since rationing would surely be an important consideration in the latter setting.

The possibility of a downward sloping demand curve is also intriguing. It seems possible that high prices might actually signal high quality for the entrant. This is indeed the case for the monopoly problem [Bagwell–Riordan (1988)], but it remains to be shown that such signalling is consistent with competition between firms. In any case, while a downward sloping demand curve might qualify our prediction of initial entrant prices below cost, it is doubtful that this extension would significantly affect the existence of the entry barrier.

Appendix 1

Proof of Proposition 1. First show that $P_2^I(\mathrm{L})=c(\mathrm{L})=P_2^e(\mathrm{L})$ is necessary for separation. Observe $P_2^I(\mathrm{L})\neq P_2^e(\mathrm{L})$ is impossible. If $P_2^e(\mathrm{L})<P_2^I(\mathrm{L})$, then L would raise price if $P_2^e(\mathrm{L})<U(\mathrm{L})$, and if $P_2^e(\mathrm{L})=U(\mathrm{L})$, I would undercut L. In the other case, if $P_2^I(\mathrm{L})<P_2^e(\mathrm{L})$, then L would undercut I if $P_2^I(\mathrm{L})>c(\mathrm{L})$, and if $P_2^I(\mathrm{L})=c(\mathrm{L})$, I would raise price slightly (and at least profit when E is L). Thus, $P_2^I(\mathrm{L})=P_2^e(\mathrm{L})$. It is then easily argued that $P_2^I(\mathrm{L})=P_2^e(\mathrm{L})=c(\mathrm{L})$. Next, separating static equilibria cannot exist in which H wins the market. Otherwise, $P_2^e(\mathrm{H})\geqq c(\mathrm{H})$ would be necessary, but then L would mimic H. Finally, $P_2^e(\mathrm{H})=U(\mathrm{H})-U(\mathrm{L})+c(\mathrm{L})$ is necessary for separation: since H loses the market, $U(\mathrm{L})-c(\mathrm{L})\geqq U(\mathrm{H})-P_2^e(\mathrm{H})$ is required for consumer optimality; in fact, $U(\mathrm{L})-c(\mathrm{L})=U(\mathrm{H})-P_2^e(\mathrm{H})$ is necessary, or I would increase its price and profit when E is H. To show existence, put $P_2^I(\mathrm{L})=c(\mathrm{L})=P_2^e(\mathrm{L})$, $P_2^e(\mathrm{H})=U(\mathrm{H})-U(\mathrm{L})+c(\mathrm{L})$, $b_2(P_2^e(\mathrm{H}))=1$ and $b_2(P_2^e)=0$ for all $P_2^e\neq P_2^e(\mathrm{H})$. The consumer is then always indifferent between E and I at the equilibrium prices, and we may require that H lose and that L win or lose Note that beliefs are rational in equilibrium. Further, it is easily verified that no firm has incentive to deviate, given these pessimistic disequilibrium beliefs.

Consider pooling next. First, if a pooling equilibrium exists in which I wins the market, then $P_2^I(\mathrm{L})=c(\mathrm{L})$ and $P_2^e(\mathrm{H})=P_2^e(\mathrm{L})=U_r-U(\mathrm{L})+c(\mathrm{L})$. The fact that I wins implies $U(\mathrm{L})-P_2^I(\mathrm{L})\geqq U_r-P_2^e(\mathrm{H})$. Note that equality is required; otherwise, I would increase price. Next $P_2^I(\mathrm{L})>c(\mathrm{L})$ is impossible: L would have incentive to undercut I. Thus $P_2^I(\mathrm{L})=c(\mathrm{L})$ and the conclusion follows. Second, if a pooling equilibrium exists in which I loses the market, then $c(\mathrm{L})\leqq P_2^I(\mathrm{L})\leqq P_2^e(\mathrm{H})=P_2^e(\mathrm{L})$ and $c(\mathrm{H})\leqq P_2^e(\mathrm{H})\leqq U_r-U(\mathrm{L})+c(\mathrm{L})$. $P_2^I(\mathrm{L})\leqq P_2^e(\mathrm{H})$ is necessary to prevent L from raising its price, and $P_2^e(\mathrm{H})\leqq U_r-U(\mathrm{L})+c(\mathrm{L})$ is necessary to prevent I from winning with the price $c(\mathrm{L})+\varepsilon$. For existence, if $U_r-U(\mathrm{L})+c(\mathrm{L})\geqq c(\mathrm{H})$, it is easily seen that the two sets of necessary conditions given above give equilibria in which I wins and loses, respectively. Put $b_2(P_2^e(\mathrm{H}))=r$ so that beliefs are rational on the equilibrium path and use pessimistic beliefs that attribute all disequilibrium prices to L. One can then verify that no agent has incentive to deviate. If

$U_r - U(\mathrm{L}) + c(\mathrm{L}) < c(\mathrm{H})$, then static pooling equilibria in which ***I*** wins (loses) cannot exist, because prices below $c(\mathrm{H})$ are dominated (unprofitable) for ***H***.

Appendix 2

We prove here Propositions 3 and 4. We begin with the following lemmas.

*Lemma 1. In any dynamic equilibrium, **I** makes zero second period profit.*

By Propositions 1 and 2, ***I*** makes zero second period profit if ***E*** pools in period one and loses the initial market, and if ***I***'s actual opponent wins this market. The 'passive' belief structure is sufficient to give zero second period profit to ***I*** if ***E*** separates and ***I***'s actual opponent loses the initial market.

*Lemma 2. In any separating dynamic equilibrium, **L** makes zero game profit.*

Suppose a separating dynamic equilibrium exists. Consider period two. ***L*** is now known or ***L*** is now believed $(r=0)$ to have a low-quality product. ***L*** thus makes zero second period profit. Consider then period one. ***L*** can profit here only if it wins the market; thus, $P_1^I(\mathrm{L}) \geqq P_1^e(\mathrm{L}) > c(\mathrm{L})$ is necessary. $P_1^e(\mathrm{L}) < P_1^I(\mathrm{L})$ is impossible: if $P_1^e(\mathrm{L}) < U(\mathrm{L})$, then ***L*** would increase price; whereas, if $P_1^e(\mathrm{L}) = U(\mathrm{L})$, then ***I*** loses the initial market and (Lemma 1) makes no game profit, so ***I*** would undercut ***L***. Thus, $P_1^I(\mathrm{L}) = P_1^e(\mathrm{L}) > c(\mathrm{L})$ is required. But then ***I*** would cut price slightly (even if ***I*** were already winning when ***E*** is ***H***).

We can now prove Proposition 3. By Lemma 2, it cannot be that a separating dynamic equilibrium exists in which [1] ***H*** wins initially with $P_1^e(\mathrm{H}) > c(\mathrm{L})$ or [2] ***H*** loses in period one. In the former case, ***L*** would mimic ***H*** for first period profits; whereas, in the latter case, ***L*** would mimic ***H*** in order to be believed $(r=1)$ ***H***, so that second period profits could be made. Thus, dynamic separation requires $P_1^e(\mathrm{H}) < c(\mathrm{L})$. Now, $P_1^I(\mathrm{L}) \geqq c(\mathrm{L})$ is true in a dynamic separating equilibrium; otherwise, ***I*** would win when ***E*** is ***L*** and make negative game profit (by Lemma 1). Thus, $P_1^e(\mathrm{H}) < c(\mathrm{L})$ is impossible: ***H*** could raise price slightly and, regardless of beliefs, continue to win the market.

We next prove Proposition 4. Necessary conditions not proved in the text are $P_1^I(\mathrm{L}) \leqq P_1^e(\mathrm{H})$ (or ***L*** would raise price slightly), $P_1^e(\mathrm{H}) \geqq c(\mathrm{L})$ (or ***L*** would make negative game profit), and $U_\delta - P_1^e(\mathrm{H}) \geqq U(\mathrm{L}) - P_1^I(\mathrm{L})$ (or the consumer would initially buy from ***I***). The necessary conditions are sufficient for the existence of a dynamic equilibrium in which ***I*** loses the first period market. Ensure rational beliefs by putting $b_1(P_1^e(\mathrm{H})) = \delta$, and construct the usual pessimistic disequilibrium beliefs, in which $b(P_1^e) = 0$ for all $P_1^e \neq P_1^e(\mathrm{H}) = P_1^e(\mathrm{L})$. The consumer is then playing optimally by visiting ***E*** (because

$U_\delta - P_1^e(\mathrm{H}) \geqq U(\mathrm{L}) - P_1^I(\mathrm{L})$). Since $P_1^e(\mathrm{H}) = P_1^e(\mathrm{L}) \leqq U_\delta - U(\mathrm{L}) + c(\mathrm{L})$, I can win only by pricing below $c(\mathrm{L})$. This is not a profitable deviation for *I*. *E* is winning and will not cut price. A price raise leads the consumer to believe *E* to be *L*, and thus to buy from *I* (since $P_1^I(\mathrm{L}) \leqq P_1^e(\mathrm{H})$). This leads to a static (second) period game with $r=0$, so the *E* would also make zero second period profit. Hence, neither *H* nor *L* will raise price.

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