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Entry deterrence and signaling in markets for search goods

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Abstract

This paper studies entry in markets for search goods. Signaling through prices is studied both when an entrant's quality is private information and when it is common knowledge to the entrant and incumbent. When consumers visit a store, they are assumed to observe quality and have the option of continuing to search but at a cost. When search costs are low, an entrant can signal high quality by setting a sufficiently high price, so that consumers who find out that its quality is low visit the incumbent. Entry may be facilitated when search costs are sufficiently low, or when the incumbent knows the quality of the entrant's product.

Keywords: Entry barriers; Search goods; Search costs; Signaling; Common information

JEL classification: D43; D82; L13; L15

1. Introduction

Being the first firm to enter a market can be advantageous – for instance, when consumers are uncertain about product quality, as in markets for search goods or experience goods.[1] If only the pioneering brand's quality is known by consumers after subsequent entry, there is informational product differentiation: consumers

[1] Search goods can be inspected to allow a quality assessment before purchase, whereas the quality of experience goods is only learned after a purchase. The distinction between experience goods and search goods was made by Nelson (1970).

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know the incumbent's quality but are uncertain about the entrant's. In such a setting, this paper explores how search costs and informational asymmetries influence the possibilities for entry in markets for search goods.

Consider a market for search goods in which consumers know the quality of the good sold by an incumbent but are uncertain about a potential entrant. The incumbent and the entrant simultaneously choose prices which are observed by consumers before they decide which firm to visit. A consumer who visits the entrant's store and finds out that product quality is too low given the price that is charged may switch to the incumbent before buying, provided that the cost of searching is not too high. It is expected that if search costs are high, then the risk of lock-in, that is, of buying a low-quality good at a high price because visiting the incumbent is too costly, may discourage consumers from visiting the entrant.

There is a variety of examples of products that have quality as a search-characteristic. Fruit vendors often allow consumers to inspect the fruit before buying. Stores selling audio equipment provide demonstrations for clients to help them decide. Automobile sellers allow consumers to perform test drives so that an assessment of quality can be made. Search costs arise, for instance, when visiting another seller takes considerable time.

The paper focuses on two questions. The first question – how do search costs affect the possibilities for entry – is posed in two different informational environments. To begin, I consider the case in which the incumbent does not know the entrant's quality (setting I). This somewhat 'standard' set-up is natural in several cases. For instance, in a fruit market the incumbent may not know who is the supplier of an entrant, so that the incumbent does not have any inside information.

The incumbent may, however, have information that consumers do not have. Consider, for instance, markets for technically complicated products, where firms have more expertise. Alternatively, consider professionals who have knowledge about each other due to a common history such as a shared education. In the model, one can allow for such events by assuming that the incumbent observes the entrant's quality (setting II). This situation gives rise to signaling with common information: the prices of both firms, rather than only the entrant's price (as in setting I), serve as signals of the entrant's type to consumers.

By examining settings I and II, one can answer a second question: is the incumbent better off if it knows the entrant's quality? A related question is: would an informed incumbent act differently, that is, will this information be used? If this is the case, industry structure might be affected. An analysis of this issue may lead to clues about inter-industry differences when industries differ by their informational environments.

Setting I, the uninformed-incumbent case, leads to several insights. One result is that the entrant can signal high quality by choosing a sufficiently high price. The intuition is that if the entrant's price is so high that a consumer who would find quality to be low would switch to the incumbent, then this price will be a credible signal of high quality.[2] Under low search costs, consumers can visit the incumbent if the entrant's quality turns out to be lower than expected. Therefore, for a separating equilibrium, it makes no sense for a low-quality seller to mimic a high type, and a firm of higher quality than the incumbent can profitably make an entrance. Moreover, for a separating equilibrium, if search costs are sufficiently high then fear of lock-in induces consumers to avoid the entrant: there is an entry barrier.

The search cost spans the separating equilibrium outcomes in an interesting way.[3] For low search costs, the equilibrium outcome of a complete-information model of Bertrand competition is obtained; the high-quality entrant captures the market. For high search costs, Bagwell's (1990) entry deterrence result in markets for experience goods is obtained (Bagwell's paper is discussed below and in Section 3.3). Thus, if search is sufficiently costly, then a search good has the characteristics of an experience good.

Pooling equilibria exist only if search costs are sufficiently high. In a pooling equilibrium the entrant charges an intermediate price (in accordance with consumers' prior beliefs). Therefore, since a high price signals high quality, if search costs are low then a high-quality entrant could deviate by increasing its price.

Setting II, the informed-incumbent case, generates additional insights. If the incumbent's price is informative about the entrant's type, then the entrant can rely on its rival's price to inform consumers, so that it has a large degree of freedom in its price choice. In the light of this observation, one can argue that the notion of perfect Bayesian equilibrium (and also sequential equilibrium) allows for unreasonable equilibria. In order to rule these out, I apply (a customized version of) Bagwell and Ramey's (1991) refinement of 'unprejudiced' sequential equilibrium. The criterion captures the idea that if a firm chooses an out-of-equilibrium signal, while its rival's equilibrium signal is informative, consumers will rely on the equilibrium signal.

If the incumbent's price is uninformative about the entrant's quality, then, by and large, the same results as in setting I are obtained. Intuitively, if consumers cannot infer the entrant's quality from the incumbent's price, it does not matter whether the incumbent actually knows the entrant's type.[4] Now suppose that the incumbent's price does depend on the entrant's type. The entrant, knowing that the incumbent can observe its type and that consumers realize this, has less difficulty in convincing consumers of high quality. As a consequence, entry is facilitated.

[2] This is true even though demand is price-inelastic. Bagwell and Riordan (1991) show that high prices may signal quality if demand is elastic and high quality is more costly to produce.

[3] I am grateful to a referee for pointing out this issue.

[4] However, a difference with setting I is that there exist pooling equilibria for a wider range of parameter values, due to the relaxed restrictions on out-of-equilibrium beliefs.

This reasoning does not depend on the level of search costs; an informative incumbent's price helps the entrant to *circumvent* lock-in effects and incentive-compatibility problems.

A comparison of settings I and II leads to the following result. The incumbent is not able to exploit private information about the entrant in a profitable way, that is, it cannot improve upon its situation if it observes the entrant's quality. The reason is that *using* information about the entrant helps the entrant to overcome its informational disadvantage. Thus, the results suggest that the distribution of information between the incumbent and the entrant is unlikely to affect industry structure.

There is a closely related literature on entry and quality uncertainty. Areeda and Turner (1975), Williamson (1977), and Demsetz (1982) argue that in markets for experience goods, promotional pricing (perhaps below marginal cost) by an entrant may be necessary to induce consumers to try its product. Accordingly, the entrant incurs 'information costs' that may be recouped when consumers purchase at a higher price after having experienced the product. Schmalensee (1982), Farrell (1986), and Bagwell (1990) formally examine the difficulty faced by a potential entrant of persuading consumers that it sells a high-quality product. The informational asymmetry may result in an entry barrier, even if the entrant's expected quality is higher than the incumbent's quality. My paper differs in two important ways. First, whereas the literature cited above considers experience goods, I examine markets for search goods.[5] As explained above, search costs crucially influence the signaling possibilities. The second difference is that I also study the case in which the entrant's type is common information.

The few papers on games with common information (that I am aware of) consider quite different issues. Matthews and Fertig (1990) study wasteful advertising by an incumbent and an entrant, both informed about the latter's quality, in a market for experience goods.[6] Entry occurs automatically, and the firms play a duopoly game in which beliefs affect demand levels. The entrant may have difficulty trying to influence beliefs because the incumbent (the second-mover) can counteract. Bagwell and Ramey (1991) investigate limit pricing by two incumbents, both informed about an industry cost parameter. Milgrom and Roberts (1986b) study competition among interested parties with common information, who try to persuade a decisionmaker to make a particular decision. These parties can only report truthful information. The main result is that competition leads to the full-information outcome.

[5] Notice the difference with Klemperer (1987) who explores entry deterrence in the presence of switching costs. In his model, a consumer who previously bought from the incumbent incurs a cost if he decides to purchase from the entrant.

[6] The literature in which firms signal quality by wasteful advertising is based on ideas in Nelson (1970); see Milgrom and Roberts (1986a).

The model of setting I is presented in Section 2, and analyzed in Section 3. Section 4 adapts the model to deal with setting II. Section 5 concludes.

2. The model of setting I

Consider a market with an incumbent (firm 1) and a potential entrant (firm 2). Entry is costless. Quality levels are expressed as (monetary) utility reservation values. The incumbent's quality is known to be low and is denoted by $q_1 = q_l$. The entrant's quality is denoted by $q_2 \in \{q_l, q_h\}$, where $q_h > q_l > 0$. The entrant's quality is determined by Nature, which selects quality q_h with probability $\alpha \in (0,1)$.[7]

The number of consumers is normalized to one with each consumer buying at most one unit. A product of quality q, sold at price p, yields utility $q - p$. The reservation utility level is zero. The unit cost of producing low quality is $c_l \geq 0$, whereas producing high quality costs $c_h \geq c_l$ per unit. Higher quality generates a higher surplus:

$$q_h - c_h > q_l - c_l > 0. \quad (1)$$

Since the central task before the entrant is to persuade consumers to visit its store, I will say that entry occurs if the entrant captures a positive share of the market. Conversely, entry is deterred if the incumbent can prevent the entrant from making sales. This terminology makes sense because the cost of entry is zero, so that strictly speaking, entry may always occur (see also Bagwell, 1990). In particular, for separating equilibria I will focus on entry by the high-quality firm and for pooling equilibria on entry by both types.

Qualities and costs are fixed during the game. The firms compete by simultaneously setting prices p_1 and p_2 which cannot be changed. Only the entrant observes its type. The expected profits of firm i are denoted by Π_i. Social welfare, denoted by W, is defined as the sum of producers' surplus and consumers' surplus.

Initially, a consumer receives information (p_1, p_2). In order to find out q_2, he has to visit the entrant's outlet. Consumers' beliefs after having observed prices are denoted by $\mu(p_1, p_2)$, which is the probability attached to the event that the entrant sells a high quality product.

At a visit to the entrant's outlet, a consumer observes q_2. At a store, a consumer

[7] Accordingly, since entry is costless and firm 2's quality is never less than that of firm 1, the entrant faces only an informational disadvantage vis-à-vis the incumbent (cf. the 'pro-entry' assumptions in Bagwell, 1990). A possible motivation for the assumption that the entrant's product is at least as good as the incumbent's is that the technology used by the incumbent is readily available. However, with probability α, the entrant realizes a successful innovation which results in high quality.

may decide not to buy, and if that happens, he may decide to visit the other firm. In the latter case, he incurs a search cost: future benefits are discounted by a factor $\delta \in [0,1]$.[8]

The sequence of events is as follows. First, Nature selects the quality of the potential entrant and this is observed by the potential entrant. Second, the two firms simultaneously set prices, which are observed by the consumers. Third, consumers (who know the quality of the incumbent, but are uncertain about the entrant's quality) decide which firm to visit. Before purchasing, they may switch to the other firm.

The notion of perfect Bayesian equilibrium of Fudenberg and Tirole (1991) is used to solve for pure strategy equilibria. Firm 2's strategy is a function $p_2(q_2)$. Equilibrium prices are denoted by p_1^* and $p_2^*(\cdot)$.[9] A consumer's strategy will be informally described by his visiting and purchasing behavior.

Definition. A perfect Bayesian equilibrium consists of firms' price strategies p_1^* and $p_2^*(q_2)$, $q_2 \in \{q_l, q_h\}$, consumers' strategy as to which firm to initially visit, and once at a firm whether to purchase, not purchase, or visit the other seller, conditional on p_1, p_2, and consumer beliefs $\mu(p_1,p_2)$, such that

(i) each firm's price strategy maximizes its profits given its rival's strategy and consumers' behavior,

(ii) consumers' decisions maximize expected net benefits given their beliefs, and

(iii) consumers' beliefs on the equilibrium path are consistent with Bayes' rule and the firms' price strategies.

Since the incumbent cannot observe the type of a potential entrant, its price cannot convey information about the entrant's quality to consumers. Accordingly, if one considers deviations by the incumbent, consumer beliefs will not vary with the incumbent's price:[10]

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[8] This way of modeling search costs is derived from Bester (1993). A higher value of δ corresponds to lower search costs.

[9] Since setting price below marginal cost is a dominated strategy, I will assume that consumers interpret a price below the unit cost of producing high quality as a signal of low quality. Also, a firm that produces low quality has no incentive to charge a price higher than the consumers' reservation value for low quality. The range of p_1, and the range of $p_2(q_l)$ will be restricted to $[c_l,q_l]$, and the range of $p_2(q_h)$ to $[c_h,q_h]$. Note that in a model of repeated purchases, these restrictions would rule out dynamic price strategies such as introductory offers.

[10] The incumbent and consumers have exactly the same information, so that in order to rule out implausible outcomes, one must require that the incumbent's price p_1 cannot influence consumers' beliefs. This is the 'no-signaling-what-you-don't-know' condition of perfect Bayesian equilibrium: a player's deviation should not signal information that he himself does not have (see Fudenberg and Tirole, 1991). This condition is implied by the consistency requirement of the sequential equilibrium concept of Kreps and Wilson (1982).

Assumption 1. Given an equilibrium price $p_2^*(q_2)$, consumers' beliefs satisfy $\mu(p_1,p_2^*(q_2))=\mu\ (p_1',p_2^*(q_2))$ for all $p_1 \neq p_1'$.

3. Analysis of setting I

In the first-best outcome (the incumbent and consumers observe the entrant's type), a high-quality entrant attracts consumers. This outcome is attained for $\delta=1$ (a situation implying consumers acquire complete information before purchasing). Equilibrium prices in this outcome are p_1^*, $p_2^*(q_l)=c_l$, and $p_2^*(q_h)=c_l+q_h-q_l$. Expected profits are $\Pi_1^*=0$ and $\Pi_2^*=\alpha(c_l+q_h-q_l-c_h)$. The first-best welfare level W^{FB} equals

$$W^{FB}=\alpha(q_h-c_h)+(1-\alpha)(q_l-c_l).$$

To start the analysis, it is convenient to introduce a parameter restriction and an assumption on consumers' beliefs. Suppose that $q_h-q_l>q_l-c_l$. Let $p_1^*\geqslant c_l$ be given. The best response of a high-quality entrant is a price $p_2^*=p_1^*+q_h-q_l$. Since $p_2^*\geqslant c_l+q_h-q_l>q_l$, price p_2^* signals high quality. Consumers are indifferent between the two firms. However, they visit the entrant; otherwise it could slightly decrease p_2^* (one can view the entrant's best response p_2^* as 'just below' $p_1^*+q_h-q_l$). Search costs or informational asymmetries do not play a role under this parameter constellation: the price of a high-quality entrant is always greater than the reservation value for low quality. To focus on more interesting cases, I will assume that

$$q_h-q_l\leqslant q_l-c_l. \tag{2}$$

Next, notice that the entrant knows that consumers can get utility level $q_l-p_1^*$ by purchasing from firm 1. Moreover, it knows that a consumer who finds out that it sells low quality will switch to the incumbent if prices are such that

$$q_l-p_2<\delta(q_l-p_1^*). \tag{3}$$

Accordingly, any price $p_2>q_l-\delta(q_l-p_1^*)$ is dominated for a low-quality entrant, while this is not necessarily the case for a high-quality firm. Therefore, given equilibrium price p_1^* (rationally expected by consumers and firm 2 in equilibrium), a price p_2 that satisfies (3) should convince consumers that firm 2 sells high quality. Formally, I will use the following assumption:[11]

[11] Assumption 2 is an equilibrium refinement strongly inclining to the Dominance Criterion of Cho and Kreps (1987) and the 'independence of never a weak best response' (INWBR) criterion of Kohlberg and Mertens (1986). See also Bester (1993), section III, for a similar beliefs restriction.

Assumption 2. Given an equilibrium price p_1^*, consumers' beliefs satisfy $\mu(p_1^*,p_2)=1$ for all p_2 such that $q_l-p_2<\delta(q_l-p_1^*)$.

3.1. Separating equilibria

In a separating equilibrium, the entrant's price is informative and hence $\mu(p_1^*,p_2^*(q_l))=0$ and $\mu(p_1^*,p_2^*(q_h))=1$. Let δ_l be defined by

$$\delta_l \equiv 1-\frac{q_h-q_l}{q_l-c_l}. \tag{4}$$

Note that $0\leq\delta_l<1$.[12]

Proposition 1. Under Assumptions 1 and 2, for any δ, there exists a unique separating equilibrium:

(i) if $\delta>\delta_l$ then a high-quality firm enters; $p_1^*=p_2^*(q_l)=c_l$ and $p_2^*(q_h)=c_l+q_h-q_l$; $\Pi_1^*=0$ and $\Pi_2^*=\alpha(c_l+q_h-q_l-c_h)$; the first-best welfare level $W=W^{FB}$ is attained;

(ii) if $\delta\leq\delta_l$ then the incumbent deters entry of a high quality firm; $p_1^*=p_2^*(q_l)=c_l$ and $p_2^*(q_h)=c_l+q_h-q_l$; $\Pi_1^*=\Pi_2^*=0$; since $W=q_l-c_l$, an inefficiency exists.

Proof. In any separating equilibrium, $p_1^*=p_2^*(q_l)=c_l$ (a price $p_1^*>c_l$ will be undercut by the low-quality entrant with a price p_2 just below p_1^*, which in turn gives firm 1 an incentive to deviate).

Suppose that in a separating equilibrium a high-quality seller attracts consumers. Two conditions must hold. First, the entrant offers a better deal than the incumbent:

$$q_h-p_2^*(q_h)\geq q_l-p_1^*. \tag{5}$$

Second, if a consumer finds out that the entrant sells low quality, he does not buy but visits the incumbent (the entrant's incentive-compatibility constraint):

$$q_l-p_2^*(q_h)<\delta(q_l-p_1^*). \tag{6}$$

From (5) and (6) it follows that $\delta>\delta_l$.

Suppose that $\delta>\delta_l$. Can an outcome in which a high-quality firm enters be supported as an equilibrium? Consider prices $p_1^*=c_l$ and $p_2^*(q_h)=c_l+q_h-q_l$, and beliefs $\mu(p_1^*,p_2)=0$ if $p_2\leq q_l-\delta(q_l-p_1^*)$, and $\mu(p_1^*,p_2)=1$ otherwise. These beliefs satisfy Assumptions 1 and 2. Suppose that consumers visit the entrant if

[12] In Proposition 1, market shares of the incumbent and low–quality entrant are not determined. Uniqueness is obtained e.g. by assuming an equal split of the market.

they observe prices p_1^* and $p_2^*(q_h)$. These strategies and beliefs constitute an equilibrium. By Assumption 2 it cannot be that $p_2^*(q_h)<c_l+q_h-q_l$ (otherwise a low type could mimic a high type).

Suppose that $\delta\leq\delta_l$. If an equilibrium exists, then the incumbent deters entry of a high-quality firm. Consequently, $q_l-p_1^*\geq q_h-p_2^*(q_h)$, so that $p_2^*(q_h)\geq c_l+q_h-q_l$. Since firm 1 should have no incentive to increase its price, $p_2^*(q_h)=c_l+q_h-q_l$. The same beliefs as in the case $\delta>\delta_l$ support this outcome as an equilibrium. □

The main insight of Proposition 1 is that a high-quality seller attracts consumers if and only if search costs are sufficiently low. Intuitively, if search costs are low enough, the entrant knows that consumers who find out that it sells low quality will switch to the incumbent, so that a low-quality type has no incentive to mimic a high-quality seller. In this case, consumers' surplus is maximal, and the first-best welfare level is attained. The range of δ in which the first-best outcome can be supported as an equilibrium outcome increases as the difference between high and low quality increases.

If the lock-in effect is severe, the risk of lock-in discourages consumers from visiting the entrant, so that there is an entry barrier, leading to an inefficient situation. Consumers are indifferent between the incumbent and the high-quality entrant. In equilibrium however, they must visit the incumbent, since otherwise a low-quality seller could profitably mimic a high-quality firm because of consumer lock-in.

3.2. Pooling equilibria

In a pooling equilibrium, $p_2^*\equiv p_2^*(q_l)=p_2^*(q_h)$. By Bayes' rule, consumers' beliefs satisfy $\mu(p_1^*,p_2^*)=\alpha$. Since, independently of firm 1's price, a price $p_2<c_h$ signals low quality and a price $p_2>q_l$ signals high quality, it must be that $c_h\leq p_2^*\leq q_l$. Necessarily, $c_h\leq q_l$ must hold.

If the entrant captures the market, then the incumbent does not make any profits. If firm 1 serves the market then it charges a price $p_1^*=c_l$; otherwise a low-quality entrant could undercut p_1^* and attract consumers. Consequently, firm 1 earns zero profits in any pooling equilibrium outcome.

By Assumption 2, any price p_2 that satisfies $q_l-p_2\leq\delta(q_l-p_1^*)$ signals high quality. Therefore, in any pooling equilibrium

$$p_2^*<q_l-\delta(q_l-p_1^*). \tag{7}$$

An implication is that if the entrant's price is uninformative, consumers who find out that it sells low quality will not switch to the incumbent. Thus if the entrant attracts consumers, they take into account that they may end up buying a low-quality product at a fairly high price. Moreover, the notion of 'entry' in the proposition below refers to the event that both types of entrant capture the market.

Proposition 2. Under Assumptions 1 and 2, pooling equilibria (with and without entry) exist if and only if $\delta \leqslant \delta_1$ *and* $\alpha \geqslant (c_h - c_l)/(q_h - q_l)$*:*

(i) *if entry occurs then* $p_1^* \in [c_l, q_l - (q_h - q_l)/(1-\delta)]$ *and* $p_2^* \in [c_h, c_l + \alpha(q_h - q_l)]$ *such that* $q_l - p_1^* \leqslant \alpha q_h + (1-\alpha) q_l - p_2^*$*;* $\Pi_1^* = 0$ *and* $\Pi_2^* = p_2^* - \alpha c_h - (1-\alpha) c_l$*; the first-best welfare level* W^{FB} *is attained;*

(ii) *if entry is deterred then* $p_1^* = c_l$ *and* $p_2^* = c_l + \alpha(q_h - q_l)$*;* $\Pi_1^* = \Pi_2^* = 0$*; since* $W = q_l - c_l$*, an inefficiency exists.*

Proof. See Appendix A.

3.3. Search goods versus experience goods

There is an important difference with Bagwell (1990), who investigates an experience good market in which consumers know that the incumbent sells low quality, and consumers and the incumbent are uncertain about the entrant. In a dynamic model, a reputation for high quality can be established by the entrant in the first of two periods. To signal its quality, a high-quality firm should select a price in the first period so low that it results in negative profits (in that period) only for the high-quality type. Thus, low prices can signal high quality. There is an entry barrier if the initial sacrifice of such a low price is prohibitively high; a low price is a costly signal. My model demonstrates that in markets for search goods, a sufficiently high price signals high quality.

An interesting link with Bagwell (1990) is the following. On the one hand, if search costs are sufficiently low ($\delta > \delta_1$; see Proposition 1), then the equilibrium outcome (in terms of equilibrium prices and consumers' behavior) is identical to the equilibrium outcome of the Bertrand model with complete information. On the other hand, for high search costs ($\delta \leqslant \delta_1$; see Proposition 1), if one considers separating equilibria, the equilibrium outcome of a static experience-goods model is obtained (see Bagwell, 1990, prop. 1, p. 212). In this sense, a search good may have the characteristics of an experience good.

4. The model and analysis of setting II

This section investigates the case in which the incumbent can observe the entrant's quality, while consumers are still uncertain. Since the incumbent's price strategy can depend on the entrant's quality, it is denoted by $p_1(q_2)$. The definition of an equilibrium given in Section 2 has to be adapted to this change. It is common knowledge that the entrant and consumers know that the incumbent is informed.[13]

[13] E.g. in the case of technically complicated goods, consumers may know that firms have the ability to assess each other's goods, whereas consumers themselves are at an informational disadvantage.

Assumption 1, no longer justifiable, is dropped. If the incumbent's price strategy satisfies $p_1^*(q_l)=p_1^*(q_h)$, then the intuition and motivation behind Assumption 2 still holds. A slightly modified version of this assumption will be applied:

Assumption 3. Given equilibrium prices $p_1^* \equiv p_1^*(q_l)=p_1^*(q_h)$, consumers' beliefs satisfy $\mu(p_1^*,p_2)=1$ for all p_2 such that $q_l-p_2<\delta(q_l\text{-}p_1^*)$.

4.1. Separating equilibria

In a separating equilibrium, at least one of the firms' prices is informative about firm 2's type, that is, $p_i^*(q_l)\neq p_i^*(q_h)$ for at least one i. Equilibrium beliefs are $\mu(p_1^*(q_l),p_2^*(q_l))=0$ and $\mu(p_1^*(q_h),p_2^*(q_h))=1$.

The fact that two firms try to signal common information may lead to unreasonable equilibria. The following example demonstrates this.

Example. Free riding on the incumbent's signal.

Consider prices $p_i^*(q_l)\neq p_i^*(q_h)$, $i=1,2$ (see Fig. 1). Let $p_1^*(q_l)=p_2^*(q_l)=c_l$. Suppose that $q_l-p_1^*(q_h)=q_h-p_2^*(q_h)$ and consumers visit the incumbent after observing price combination $(p_1^*(q_h),p_2^*(q_h))$. Let consumer beliefs be such that firm 2 has no incentive to decrease its price, that is,

$$\mu(p_1^*(q_h),p_2)q_h+(1-\mu(p_1^*(q_h),p_2))q_l-p_2\leq q_l-p_1^*(q_h),\ p_2<p_2^*(q_h).$$

For instance, $\mu(p_1^*(q_h),p_2)=0$ for all $p_2<p_2^*(q_h)$; if the high-quality entrant would reduce its price, consumers would believe that it sells low quality. Also, $p_1^*(q_h)\leq c_h$ must hold, because otherwise the entrant could profitably deviate with a price below the incumbent's price (with the purpose of mimicking a low-quality seller). Accordingly, we have an equilibrium. Firm 1's profits equal $\Pi_1^*=$

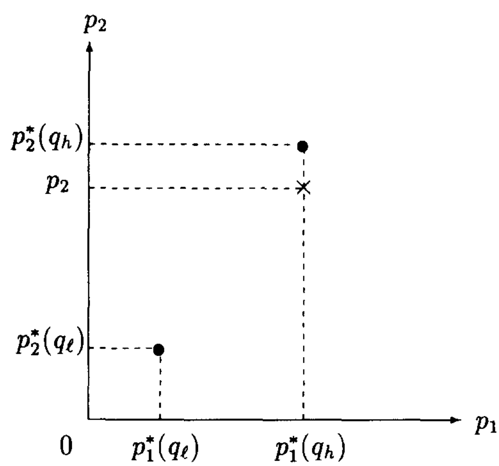

Fig. 1. A separating equilibrium.

$\alpha(p_1^*(q_h)-c_1)$; higher than in any equilibrium in the model of the previous section. Accordingly, one might conclude that having more information can be beneficial for the incumbent.

However, the beliefs supporting the equilibrium in the example above raise serious doubts. If firm 2 slightly decreases its price to p_2 (see Fig. 1), a consumer who observes $(p_1^*(q_h),p_2)$ can deduce the entrant's quality from the incumbent's price. To see this, notice that the entrant knows that the incumbent observes q_2, and that consumers realize this. Since $p_1^*(q_l)\neq p_1^*(q_h)$, the incumbent's price remains informative about the entrant's type if the entrant deviates. Consumers may therefore reason that firm 1 would not have selected $p_1^*(q_h)$ if firm 2's quality is low. Consequently, prices $(p_1^*(q_h),p_2)$ should make consumers believe that firm 2 sells high quality. Since $q_h-p_2>q_l-p_1^*(q_h)$, the entrant can 'free ride' on the incumbent's signal.[14]

The example demonstrates that the equilibrium notion needs further refinement. Bagwell and Ramey (1991) give a similar example (in a limit-pricing model with multiple incumbents), which suggests that 'free riding on the rival's signal' is a general problem when there is common information. They formulate a restriction on beliefs for signaling games with common information ('unprejudiced' beliefs).[15] For convenience, I use a different but equivalent formulation of their criterion. To do so, a definition is given:

Definition. In an equilibrium with prices $p_1^*(q_2)$ and $p_2^*(q_2)$, $q_2\in\{q_l,q_h\}$, price vector (p_1,p_2) is said to be weakly consistent with $q_2\in\{q_l,q_h\}$ if there exists an $i\in\{1,2\}$ such that $p_i=p_i^*(q_2)$.

[14] The concept of sequential equilibrium does not eliminate the equilibrium in the example. Consider, for the sake of argument, discrete prices (the formal definition of sequential equilibrium only applies to games with finite spaces). Suppose that the set of possible prices for firm i is $\{p_i^*(q_l),p_i^*(q_h),p_i\}$, for some $p_i\in(p_i^*(q_l),p_i^*(q_h))$. We will check whether the equilibrium strategies $p_i^*(\cdot)$ satisfy the consistency requirement of sequential equilibrium. If $q_2=q_l$, let firm i tremble (choose each price different from $p_i^*(q_l)$) with probability $\epsilon>0$. If $q_2=q_h$, let firm 1 tremble with probability ϵ, and firm 2 with probability ϵ^3. What should a consumer who observes prices $(p_1^*(q_h),p_2)$ believe? Beliefs defined by Bayes' rule from the set of completely mixed strategies are $\mu^\epsilon(p_1^*(q_h),p_2)=[\alpha(1\text{-}2\epsilon)\epsilon^3]/[\alpha(1\text{-}2\epsilon)\epsilon^3+(1\text{-}\alpha)\epsilon^2]$. Now $\lim_{\epsilon\to 0}\mu^\epsilon(p_1^*(q_h),p_2)=0$, i.e. the consistency requirement is satisfied. As argued in Bagwell and Ramey (1991), requiring that all trembles have the same magnitude would eliminate the equilibrium.

[15] Bagwell and Ramey (1991) provide a somewhat different motivation for their beliefs restriction. In my example, their argument would be that consumers observing $(p_1^*(q_h),p_2)$ should believe that the entrant's quality is high because then one deviation instead of two occurred; consumers should not be 'prejudiced' in believing that any deviation is more likely than any other. Their notion of unprejudiced sequential equilibrium requires that a deviant price pair is rationalized with the fewest deviations.

In the rest of this paper, beliefs in a perfect Bayesian equilibrium have to satisfy Assumption 3 and the following criterion:

Assumption 4. Let equilibrium prices $p_1^*(q_2)$ and $p_2^*(q_2)$, $q_2 \in \{q_l, q_h\}$, be given.

(i) Consider prices $p_1, p_2 \in [c_l, q_l]$. If (p_1, p_2) is weakly consistent with q_l, but not with q_h, then $\mu(p_1, p_2) = 0$.

(ii) Consider prices $p_1 \in [c_l, q_l]$ and $p_2 \in [c_h, q_h]$. If (p_1, p_2) is weakly consistent with q_h, but not with q_l, then $\mu(p_1, p_2) = 1$.

Assumption 4 explicitly takes into account the common information aspect of the game. In the example above, $(p_1^*(q_h), p_2)$ is weakly consistent with q_h, but not with q_l. Consequently, after observing equilibrium price $p_1^*(q_h)$ and deviation p_2, consumers believe that the entrant sells high quality. Since it is sufficient to pin down out-of-equilibrium beliefs only for slight deviations, a weaker formulation of the refinement will also do the job.

Appendix A derives necessary conditions on informative equilibrium prices (Lemmas A.1–A.3). I will briefly discuss some of them. First, if the incumbent deters entry of a high-quality seller, then the incumbent's price must be uninformative, that is, $p_1^*(q_l) = p_1^*(q_h)$. This result generalizes the example above and is a consequence of Assumption 4. An informative price strategy by firm 1 that deters entry cannot occur in equilibrium, since it allows a high-quality entrant to convince consumers of high quality and attract consumers. An implication is that an incumbent who wants to adopt a 'tough' posture (in the sense of making entry difficult) should employ a strategy that does not convey information about the entrant. Second, if a high-quality seller captures the market, then $p_1^*(q_l) \geq p_1^*(q_h)$; the incumbent sets an equally or more aggressive price if it faces a high-quality rival.

Proposition 3. Under Assumptions 3 and 4, for any δ, there exist exactly two separating equilibria:

(i) *if $\delta > \delta_1$ then there exists a separating equilibrium in which a high-quality firm enters, and $p_1^* \equiv p_1^*(q_l) = p_1^*(q_h) = c_l$, $p_2^*(q_l) = c_l$, and $p_2^*(q_h) = c_l + q_h - q_l$; $\Pi_1^* = 0$ and $\Pi_2^* = \alpha(c_l + q_h - q_l - c_h)$; the first-best welfare level W^{FB} is attained;*

(ii) *if $\delta \leq \delta_1$ then there exists a separating equilibrium in which the incumbent deters entry of a high-quality firm, and $p_1^* \equiv p_1^*(q_l) = p_1^*(q_h) = c_l$, $p_2^*(q_l) = c_l$, and $p_2^*(q_h) = c_l + q_h - q_l$; $\Pi_1^* = \Pi_2^* = 0$; since $W = q_l - c_l$, an inefficiency exists;*

(iii) *for any δ there exists a separating equilibrium in which each type of firm enters (i.e. consumers visit and buy from each type of firm 2); in this equilibrium $p_1^*(q_l) = c_l + q_h - q_l$, $p_1^*(q_h) = c_l$, $p_2^* \equiv p_2^*(q_l) = p_2^*(q_h) = c_l + q_h - q_l$; $\Pi_1^* = 0$ and $\Pi_2^* = c_l + q_h - q_l - c_h$; the first-best welfare level W^{FB} is attained.*

Proof. (i) For necessary conditions on the prices when a high-quality firm enters, see Lemmas A.1 and A.3 in Appendix A. Given that $p_1^* \equiv p_1^*(q_l) = p_1^*(q_h)$, the proof of Proposition 1 (i) applies to show that $\delta > \delta_1$ is necessary and sufficient. Beliefs $\mu(p_1, p_2^*(q_l)) = 0$ and $\mu(p_1, p_2^*(q_h)) = 1$, for all p_1, satisfy the refinement criterion.

(ii) For necessary conditions on the prices when entry is deterred, see Lemmas A.1 and A.2. Since $p_1^* \equiv p_1^*(q_l) = p_1^*(q_h)$, the proof of Proposition 1 (ii) applies to show that $\delta \leq \delta_1$ is necessary and sufficient. As in (i), beliefs satisfy Assumptions 3 and 4.

(iii) See Lemmas A.1 and A.3. One can support the equilibrium prices, for any value of δ, with beliefs $\mu(p_1^*(q_l), p_2) = 0 \ \forall p_2$; $\mu(p_1^*(q_h), p_2) = 1 \ \forall p_2$; $\mu(p_1, p_2^*) = 1 \ \forall p_1 < p_1^*(q_l)$; and $\mu(p_1, p_2^*) = 0 \ \forall p_1 \geq p_1^*(q_l)$. If consumers do not visit firm 2 in equilibrium, then firm 2 can slightly decrease its price and attract consumers, a contradiction. □

In parts (i) and (ii) of the proposition, the incumbent's price is uninformative. Accordingly, search costs play the same role as in the model of the previous section. Part (iii) of Proposition 3 shows that, contrary to setting I, for any value of δ there exists a separating equilibrium with entry. In this equilibrium, the incumbent's price reveals the entrant's type to consumers. The reason that search costs do not play a role is that a low-quality entrant by itself cannot mimic a high-quality type, since the incumbent's price would still inform consumers that the entrant sells low quality. The incumbent charges a relatively high price to signal that the entrant sells low quality, and a relatively low price in the opposite case.[16] Note that the first-best welfare level is attained in this outcome.

4.2. Pooling equilibria

Any pooling equilibrium of the model in the previous section is also an equilibrium in this model (the only difference is that Assumption 1 has been dropped). By and large, the intuition behind Proposition 2 applies – see the discussion of condition (7) in the previous section. As in Proposition 2, 'entry' means that each type of new firm captures the market. Because of the larger degree of freedom in defining consumer beliefs out of equilibrium, additional pooling equilibria may exist. In particular, pooling equilibria exist for any $\alpha \in (0,1)$.

[16] There is an argument against this equilibrium. In the spirit of Grossman and Perry's (1986) perfect sequential equilibrium, beliefs $\mu(p_1, p_2^*) = 1$ for $p_1 \in (p_1^*(q_h), p_1^*(q_l))$ are not reasonable. Since firm 1 attracts no consumers in equilibrium, each 'type' of incumbent has the same incentive to select a price $p_1 < p_1^*(q_l)$. Therefore after a deviation by firm 1, consumers should not draw any conclusion about the entrant's quality: $\mu(p_1, p_2^*) = \alpha$. Then firm 1 is able to attract consumers by deviating.

Proposition 4. Under Assumptions 3 and 4, pooling equilibria (with and without entry) exist if and only if $\delta \leqslant \delta_1$:

(i) *if entry occurs then* $p_1^* \in [c_1, q_1 - (q_h - q_1)/(1-\delta)]$ *and* $p_2^* \in [c_h, c_1 + q_h - q_1]$ *such that* $q_1 - p_1^* \leqslant \alpha q_h + (1-\alpha) q_1 - p_2^*$ *and* (7) *holds;* $\Pi_1^* = 0$ *and* $\Pi_2^* = p_2^* - \alpha c_h - (1-\alpha) c_1$; *the first-best welfare level* W^{FB} *is attained;*

(ii) *if entry is deterred then* $p_1^* = c_1$ *and* $p_2^* \in [c_h, c_1 + q_h - q_1]$ *such that* $p_2^* \geqslant c_1 + \alpha(q_h - q_1)$ *and* (7) *holds;* $\Pi_1^* = \Pi_2^* = 0$; *since* $W = q_1 - c_1$, *an inefficiency exists.*

Proof. See Appendix A.

4.3. The role of the incumbent's information

By comparing settings I and II, one can assess whether the incumbent benefits from knowing the entrant's quality (and the entrant and consumers knowing that the incumbent knows, and so forth). If one considers separating equilibria, for any level of search costs there exists an additional equilibrium in setting II (see Proposition 3 (iii)). In this equilibrium, consumers visit both types of the entrant. Since in setting I entry cannot occur if search costs are high (see Proposition 1 (ii)), an informed incumbent may help the entrant to persuade consumers to visit it. From a welfare point of view, common information may restore efficiency for sufficiently high search costs (compare Propositions 1 (ii) and 3 (iii)).

In setting II, there exist pooling equilibria with and without entry for a wider array of parameter values. One cannot, however, draw clear-cut conclusions concerning the possibilities of entry. Under common information, however, it is possible that if entry occurs the entrant charges a higher price than in any pooling equilibrium without common information. As a consequence the incumbent's additional information may increase the entrant's profits and decrease consumers' surplus.

The results of the analysis imply that the incumbent cannot benefit from observing the entrant's quality. At first sight, this result may look surprising. One would perhaps expect that it would be advantageous for the incumbent to have this information.[17] Intuitively, the entrant, who knows that the incumbent is informed, and knows that consumers know this, has an incentive to exploit informative strategies of the incumbent. The role played by Assumption 4 implies a caveat – namely, that without the assumption, information about an entrant could be valuable to the incumbent (as shown in the opening example of this section).

[17] For instance, Bagwell (1990) presumes (in a model with experience goods, see the discussion in the previous section) that "... the entrant would be worse off if its type were known to the incumbent" (footnote 4, p. 210).

5. Conclusion

To conclude, I will briefly recapitulate some particular signaling possibilities in the model. First, in markets for search goods, a high price can signal high quality. The intuition is that a low-quality entrant is discouraged from mimicking a high-quality type by consumers' credible threat to visit the incumbent should they find out that quality is low.

Second, if the incumbent can observe the entrant's type, it is optimal not to take advantage of this opportunity. The entrant, who knows that the incumbent can observe its type and that consumers realize this, faces less difficulty in convincing consumers of high quality if the incumbent's strategy contains information. In particular, if the incumbent's price is informative then the entrant can circumvent lock-in effects and entry is possible for any level of search costs.

An interesting extension of the model is to consider the choice of location as a quality signal. Nelson (1970) already argued that stores selling search goods have an incentive to cluster. Recall that a price such that a consumer who would observe low quality in the entrant's store would visit the incumbent signals high quality. Thus, if search costs are low, consumers are more easily convinced of high quality. One can endogenize search costs by having the entrant choose its location. An interesting question is why sellers often locate near to each other, despite increased competition; an example is a fruit and vegetables market.

Another direction for further research is to allow the incumbent to spy on an entrant to observe its quality. This information may, however, be of value to the incumbent. The reason is that if the entrant is not sure whether it has been spied upon, it cannot rely on the incumbent's strategy to signal its type.

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Appendix A

Proof of Proposition 2.

In any pooling equilibrium, condition (7) must hold (see Section 3.2). Also, a high-quality entrant must not be able to offer a more favorable deal than the incumbent by charging a price that convinces consumers of high quality, that is, $q_h - p_2 \leq q_l - p_1^*$ for all $p_2 \geq q_l - \delta(q_l - p_1^*)$. Equivalently,

$$p_1^* \leq q_l - \frac{q_h - q_l}{1 - \delta}. \tag{A.1}$$

There exists a price $p_1^* \geq c_l$ satisfying (A.1) if and only if $\delta \leq \delta_l$.

(i) The entrant attracts consumers only if $q_l - p_1^* \leq \alpha q_h + (1-\alpha) q_l - p_2^*$. If $p_1^* > c_l$, then firm 1 has no incentive to decrease its price if $q_l - p_1 \leq \alpha q_h + (1 - \alpha) q_l - p_2^*$ for all $p_1 \in (c_l, p_1^*)$. Equivalently, $p_2^* \leq c_l + \alpha(q_h - q_l)$. The latter condition must also hold if $p_1^* = c_l$. Since any price $p_2 < c_h$ signals low quality, $p_2^* \geq c_h$. Combining these two constraints, it follows that $\alpha \geq (c_h - c_l)/(q_h - q_l)$. There exists a $p_1^* \geq c_l$ that satisfies (A.1) if and only if $\delta \leq \delta_l$. Since $p_2^* \leq c_l + \alpha(q_h - q_l) < c_l + q_h - q_l$ and $p_1^* \geq c_l$, a sufficient condition for (7) is $c_l + q_h - q_l \leq q_l - \delta(q_l - c_l)$. The latter condition is equivalent to $\delta \leq \delta_l$. The equilibrium outcome can be supported by beliefs $\mu(p_1^*, p_2) \leq \alpha$ for all $p_2 \in (c_h, q_l - \delta(q_l - c_l))$.

(ii) It must be that $p_1^* = c_l$ (see Section 3.2). The incumbent cannot attract consumers by a price increase only if $q_l - p_1^* = \alpha q_h + (1-\alpha) q_l - p_2^*$, so that $p_2^* = c_l + \alpha(q_h - q_l)$. Since $p_2^* \geq c_h$, it follows that $\alpha \geq (c_h - c_l)/(q_h - q_l)$. Inequality (A.1) holds if and only if $\delta \leq \delta_l$. As in (i), $\delta \leq \delta_l$ implies condition (7). The equilibrium outcome can be supported by beliefs $\mu(p_1^*, p_2) \leq \alpha$ for all $p_2 \in (c_h, p_2^*) \cup (p_2^*, q_l - \delta(q_l - c_l))$. □

Lemma A.1. A necessary condition for separating equilibria.

$$q_l - p_1^*(q_h) = q_h - p_2^*(q_h).$$

Proof. If $q_l - p_1^*(q_h) > q_h - p_2^*(q_h)$, then firm 1 can increase its price, a contradiction. Therefore, suppose $q_l - p_1^*(q_h) < q_h - p_2^*(q_h)$. If $p_1^*(q_l) \neq p_1^*(q_h)$, then there exists a price $p_2 > p_2^*(q_h)$ such that $q_l - p_1^*(q_h) \leq q_h - p_2$ and $p_2 \neq p_2^*(q_l)$, that is, $(p_1^*(q_h), p_2)$ is weakly consistent with q_h, but not with q_l. According to the refinement criterion, $\mu(p_1^*(q_h), p_2) = 1$. Therefore, firm 2 can increase its price and attract consumers, a contradiction. Consequently, $p_1^* \equiv p_1^*(q_l) = p_1^*(q_h)$. Since consumers visit the entrant in case of high quality, a low − quality entrant must not be able to mimic a high type, that is, $q_l - p_2^*(q_h) \delta(q_l - p_1^*)$ must hold. But then any price $p_2 > p_2^*(q_h)$ satisfies $q_l - p_2^* < \delta(q_l - p_1^*)$. By Assumption 3, a high-quality entrant has an incentive to increase its price, a contradiction. □

Lemma A.2. Necessary conditions for separating equilibria.
Suppose that consumers observe $(p_1^*(q_h), p_2^*(q_h))$. If they visit firm 1 then
(i) $p_1^* \equiv p_1^*(q_l) = p_1^*(q_h)$, and
(ii) $p_1^* = c_l$, $p_2^*(q_l) = c_l$ and $p_2^*(q_h) = c_l + q_h - q_l$.

Proof. (i) Suppose that $p_1^*(q_l) \neq p_1^*(q_h)$. By Lemma A.1 and (1), $p_2^*(q_h) = p_1^*(q_h) + q_h - q_l > c_h$. There exists a price $p_2 < p_2^*(q_h)$ such that $(p_1^*(q_h), p_2)$ is weakly consistent with q_h, but not with q_l. Thus $\mu(p_1^*(q_h), p_2) = 1$, and firm 2 can attract consumers by decreasing its price – a contradiction.

(ii) If $p_1^* > c_l$, then in case of $q_2 = q_l$, the entrant captures the market at a price $p_2^*(q_l)$ just below p_1^*. There exists a price $p_1 \in (c_l, p_2^*(q_l))$ such that $(p_1, p_2^*(q_l))$ is weakly consistent with q_l, but not with q_h. Hence $\mu(p_1, p_2^*(q_l)) = 0$, and firm 1 can increase its profits by undercutting firm 2 after observing that $q_2 = q_l$, a contradiction. Therefore, $p_1^* = c_l$. Moreover, $p_2^*(q_l) = c_l$, since otherwise firm 1 would have an incentive to increase $p_1^*(q_l)$. From Lemma A.1 it follows that $p_2^*(q_h) = c_l + q_h - q_l$. □

Lemma A.3. Necessary conditions for separating equilibria.

Suppose that consumers observe $(p_1^*(q_h), p_2^*(q_h))$. If they visit firm 2 then

(i) *either* $p_1^*(q_l) = c_l$ *and* $p_2^*(q_l) = c_l$*; or* $p_1^*(q_l) = c_l + q_h - q_l$ *and* $p_2^*(q_l) = c_l + q_h - q_l$*, and*

(ii) $p_1^*(q_h) = c_l$ *and* $p_2^*(q_h) = c_l + q_h - q_l$.

Proof (in reverse order). (ii) Notice that $p_1^*(q_h) = c_l$, otherwise firm 1 could attract consumers by decreasing its price. By Lemma A.1, $p_2^*(q_h) = c_l + q_h - q_l$.

(i) First, suppose that $p_2^*(q_l) \neq p_2^*(q_h)$. If $q_l - p_1^*(q_l) > q_l - p_2^*(q_l)$ then, by the refinement criterion, firm 1 can increase its price. If $q_l - p_1^*(q_l) < q_l - p_2^*(q_l)$, then firm 2 can increase its price. Therefore, $q_l - p_1^*(q_l) = q_l - p_2^*(q_l)$. From similar arguments it follows that $p_1^*(q_l) = c_l$ and $p_2^*(q_l) = c_l$.

Second, suppose that $p_2^*(q_l) = p_2^*(q_h)$. Therefore, $p_1^*(q_l) > p_1^*(q_h)$. If $q_l - p_1^*(q_l) > q_l - p_2^*(q_l)$ then the incumbent has an incentive to pretend that it observed a low-quality entrant by selecting $p_1^*(q_l)$ if the entrant's actual quality is high. If $q_l - p_1^*(q_l) < q_p - p_2^*(q_l)$, then firm 2 can increase its price. It follows that $q_l - p_1^*(q_l) = q_l - p_2^*(q_l)$ (and consumers visit the entrant). Accordingly $p_1^*(q_l) = c_l + q_h - q_l$. □

Proof of Proposition 4.

In any pooling equilibrium, (7) and (A.1) must hold. Firm 1 should not have an incentive to deviate with some price $p_1 > c_l$. Let $\mu(p_1, p_2^*) = 1$ for such a deviation, so that it is sufficient to require $q_l - p_1 \leq q_h - p_2^*$ for all $p_1 > c_l$. Equivalently, $p_2^* \leq c_l + q_h - q_l$. Entry occurs only if $q_l - p_1^* \leq \alpha q_h + (1-\alpha) q_l - p_2^*$. Entry is deterred only if $q_l - p_1^* \geq \alpha q_h + (1-\alpha) q_l - p_2^*$. Also, if entry is deterred then $p_1^* = c_l$. The equilibrium outcomes can be supported by beliefs $\mu(p_1^*, p_2)$ similar to those in the proof of Proposition 2. □

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