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Entry Blockading Locations

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Entry Blockading Locations[*]

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Résumé / Abstract

Comment l'information asymétrique (sur les coûts de production) en concurrence spatiale modifie-t-elle le comportement d'une firme établie capable de s'engager de manière crédible à une localisation donnée? Bien que la dissuasion d'entrer ne soit pas pertinente dans ce contexte, nous montrons que la firme établie peut parfois bloquer l'entrée grâce ou bien à son avantage technologique ou bien aux croyances de l'entrant quant à cet avantage. Nous caractérisons pour différents niveaux de coûts fixes et variables l'unique équilibre K-imbattu. Nous montrons que les croyances de l'entrant sont importantes pour la détermination des stratégies d'équilibre. Ainsi, le centre du marché peut être une localisation bloquante en information incomplète pour une firme établie non-avantagée qui, en information complète, choisirait une localisation accomodante. Par ailleurs, nous montrons qu'une firme établie avantagée capable en information complète de bloquer l'entrée en se localisant au centre du marché pourrait choisir en information incomplète une localisation accomodante.

How does asymmetric information (regarding production costs) in a spatial market alter the behavior of the incumbent firm which can credibly commit to her location choice? Although entry deterrence is irrelevant here, our analysis shows that entry blockading behavior emerges not only as the result of the incumbent's technological advantage but also as the result of the entrant's beliefs concerning this technological advantage. Using the concept of K-undefeated equilibrium, we characterize the unique location equilibrium for different values of the fixed and variable costs and we show that the conjecture formed by the entrant regarding the incumbent's location strategy does matter for the determination of the equilibrium strategies. First, we show that the market center may be an entry blockading location under incomplete information for a high cost inefficient incumbent who would accommodate entry under complete information. Second, we show that a low cost efficient incumbent who blockades entry at the market center under complete information may be better off to accommodate entry under incomplete information.

Mots clés :	Localisation, entrée, information incomplète
Keywords :	Location, Entry, Incomplete Information

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1 INTRODUCTION

Bain (1956) has suggested that an incumbent facing potential entry can follow one of three kinds of strategies. The incumbent *blockades* entry if, in choosing the same strategies that would be chosen were there no threat of entry, entry is prevented. When entry cannot be blockaded, the incumbent *deters* entry if she can alter her strategies chosen under no threat of entry such that she successfully impedes entry. Finally, the incumbent *accommodates* entry if she finds it more profitable to let a competitor enter the market than to erect costly barriers to entry.

Following Bain's classification of entry possibilities, economic theorists first focused on price or quantity as a barrier to entry. Dixit (1979) has shown that a classification of cases along the lines of Bain is possible either under the 'Sylos-Labini postulate', where a level of output is chosen and maintained forever whether or not entry occurs, or under the possibility suggested by Wenders (1971) and Spence (1977), that entry can be prevented by the incumbent using a credible threat to produce a large enough post-entry output. However, the conclusion that an incumbent may at equilibrium deter entry was based in some cases upon the strong assumption that she could commit to a price chosen at pre-entry, which is another way to formulate the Sylos-Labini postulate. Milgrom and Roberts (1982) have shown that were this assumption relaxed, there would be no limit pricing in any complete information model, hence entry could not be deterred as defined by Bain. They modeled the problem of entry deterrence as a game of incomplete information in order that limit pricing behavior emerges endogenously in equilibrium: when a potential entrant does not know the incumbent's cost level, the latter may discourage entry by charging a pre-entry price below her monopoly price in order to signal that she is a low cost incumbent, hence a potentially more aggressive competitor if entry occurs.

Bain's classification remains valid in the context of differentiated products. Consider the following competitive structure: first, the incumbent selects the quality or location of her product; second, a potential entrant observes this choice and decides to enter if he can guarantee himself positive profits (net of fixed cost); third, if entry occurs the firms compete in prices and if not, the incumbent monopolizes the market. This sequence of moves leads to a game-theoretic equilibrium formulation which is a proper and relevant way to analyze entry deterrence.[†]

In such a spatial setup, the incumbent is assumed to commit to a chosen location. Unlike price commitment, it is natural to think that an established firm can credibly commit to a location because it may reasonably be assumed that relocation is costly and therefore that location is irreversible. Despite such a commitment, it is not obvious that entry deterrence should find formal justification under complete information in a model where the incumbent's

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[†]See for example Bonanno (1987), Anderson, de Palma and Thisse (1992), Donnenfeld and Weber (1995). Note however that the expression "deterring entry" is often used also in the sense of "blockading entry".

choice is restricted to a single location in a spatial market with a uniform or symmetric unimodal distribution of consumers. Indeed, the market center is not only the optimal location for a monopolist in absence of an entry threat but also the location that minimizes the maximum attainable gross profit of the potential entrant: there is no way to deter entry by moving to a location away from the center. Entry is either *blockaded* for values of the fixed cost that are larger than the entrant's gross profit or *accommodated*, but it cannot be *deterred* as defined by Bain. This conclusion holds under the assumption that consumers are uniformly distributed over the market line segment. However, it may not hold if the density of consumers is skewed towards one side of the market. Then the central location is no longer the optimal location for an incumbent in absence of an entry threat since transportation costs are more important on the side of the market where consumers are more numerous. But the market center is still the location that triggers the highest degree of expected competition that an entrant faces whatever his location. Hence the market center may be an entry deterrent strategy as defined by Bain.

In our analysis we maintain the assumption of an uniform density of consumers in order to focus on two of the three strategies considered by Bain: the entry blockading strategy versus the entry accommodating strategy. Our main concern is to study how asymmetric information alters the behavior of an established firm in a spatial market. Contrary to the limit pricing results of Milgrom and Roberts (1982), there is no entry deterring strategy under incomplete information in the present case - recall that our model is different in that the incumbent can credibly commit to her pre-entry location choice. Moreover, our analysis shows that entry blockading behavior emerges not only as the result of the incumbent's technological advantage, that is, of the high fixed cost of entry and the production cost gap under complete information as presented in the standard literature, but also as the result of the entrant's beliefs concerning this technological advantage. Expectations may be self-fulfilling in a context of incomplete information. Thus an incumbent may rationally accommodate entry because she is not considered to be sufficiently strong to blockade entry even if she would indeed be that strong when properly identified.

The potential entrant is assumed to be imperfectly informed about some characteristic of the established firm which is relevant to his post-entry profit. In our model this characteristic is the incumbent's production cost which we assume to be her private information. We assume that the incumbent is at least as efficient as the entrant, that is, her unit production cost is lower than or the same as the entrant's and the latter does not know whether he faces a more efficient competitor or a similarly efficient one. We concentrate on spatial differentiation and assume that firms choose their locations sequentially before they simultaneously compete in delivered prices. If the entrant decides to enter, the true cost of the incumbent is revealed before the price competition stage as in Milgrom and Roberts (1982). In order to avoid trivialities, we focus on the case in which, under complete information, the more efficient incumbent would

blockade entry at the market center whereas the less efficient incumbent would accommodate entry, thus the fixed cost of the potential entrant is neither too small nor too large. The inability of the Perfect Bayesian Equilibrium concept to determine a potential entrant's posterior beliefs if an out-of-equilibrium location is observed results in a multiplicity of equilibrium location configurations. However, it is possible to define what reasonable beliefs should be in such cases. We will make use here of a notion closely related to the notion of "undefeated equilibrium", a particularly interesting refinement proposed by Mailath, Okuno-Fujiwara and Postlewaite (1993). Our "K-undefeated equilibrium" concept will turn out to be powerful enough in the present context to single out a reasonable equilibrium.[‡] We focus on pure strategy equilibria, hence on the sole separating and pooling equilibria. The case of mixed strategy equilibria when fixed costs are negligible have been analyzed in Boyer, Laffont, Mahenc and Moreaux (1994, 1995). Allowing for mixed strategies would give no additional insights to the entry preventing role of the fixed costs.

Our main results are as follows. We single out a K-undefeated equilibrium for different values of the fixed and variable costs and we show that the conjecture formed by the entrant regarding the incumbent's location strategy does matter for the determination of the equilibrium strategies. We will consider the entrant to be optimistic (pessimistic) if he puts a priori less (more) probability on the more efficient incumbent. In terms of equilibrium or predicted locations, we first show that the market center may be an entry blockading location under incomplete information for a high cost inefficient incumbent who would accommodate entry under complete information. Second, we show that a low cost efficient incumbent who blockades entry at the market center under complete information may be better off to accommodate entry under incomplete information.

The intuition behind these results is that the pre-entry location becomes a signal regarding the incumbent's unit cost. If the entrant is sufficiently pessimistic, the market center emerges as an entry blockading equilibrium for the high cost incumbent because information is not disclosed in equilibrium: she finds it profitable to mimic her low cost counterpart and therefore the market center is the only plausible equilibrium location. In equilibrium the potential entrant remains uncertain about his competitor's cost and stays out whereas he would enter and compete against a high cost incumbent under full information. The low cost incumbent remains at the market center, her full information equilibrium location from which she blockades entry. However, if the entrant is sufficiently optimistic, that is, if he expects instead the incumbent to be a high cost one with the same unit cost as his, the entrant enters the market whatever the incumbent's location

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[‡]The better known refinements such as Kreps' intuitive criterion, Cho and Kreps' D1 divinity criterion or Grossman and Perry's sequential perfectness criterion fail to generate a unique reasonable equilibrium in the present case; the undefeated criterion of Mailath, Okuno-Fujiwara and Postlewaite (1993) is almost powerful enough but not quite.

and true cost. Since the incumbent fails to prevent entry even if she is in fact more efficient than the entrant, locating at the market center exacerbates the level of post-entry competition. Thus, when the entrant is sufficiently optimistic, not only is the market center no longer an entry-blockading location but it also cannot be an equilibrium location for the incumbent of either the high cost or low cost type. The low cost incumbent then finds it profitable to locate away from the market center and accommodate entry. Two cases may be distinguished according to technological characteristics: the fixed and variable costs. Either separation of the types is possible and the low-cost incumbent discloses her true cost by locating in an area where the high-cost incumbent wouldn't locate, or separation of the types is not possible and a pooling equilibrium emerges. In both cases the low-cost incumbent prefers to move away from the market center to benefit from a higher degree of product differentiation, hence a lower degree of post-entry competition.

The paper is organized as follows. We present the basic model and the full information benchmark in section 2. We devote section 3 to the concepts and tools used to study the incomplete information case. The characterization of the Perfect Bayesian Equilibria is achieved in section 4 and the K-undefeated equilibria among the Perfect Bayesian Equilibria are characterized in section 5. We then conclude by summarizing the most striking results of the paper.

2   THE MODEL AND THE COMPLETE INFORMATION BENCHMARK

We consider a continuum of consumers uniformly distributed on a segment $[0, 1]$ with unit density. Each consumer demands one unit of the good, provided that its price is not higher than the reservation value r. An established firm and a potential entrant are involved in a two stage game. In the first stage the incumbent chooses her location and the entrant makes two simultaneous decisions: to enter the market or not, and upon entry, to locate a single plant. The firms move sequentially and the incumbent, denoted as firm 1, is the first mover. Entry implies a fixed cost and locations are irreversible. In the second stage of the game the firms compete in delivered prices as in Hurter and Lederer (1985) and Lederer and Hurter (1986). In the first stage of the game, firm 2 observes only the location decision of firm 1 before deciding on its own entry and location. As usual in this kind of model since the seminal work of Milgrom and Roberts (1982), we suppose that firm 2 will know firms 1's type before the price competition takes place in stage 2. Finally, the two firms are risk neutral, hence maximize their expected profit.

If it enters, firm 2 incurs a constant average variable cost c and a fixed cost f. The incumbent

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incurs only a variable cost and is assumed to be either strong or weak. We will refer to firm 1 with constant average variable cost 0 and c as the low and high cost types respectively. Let $T = \{t \mid t \in \{h, \ell\}\}$ be the set of types, with h (ℓ) being the high (low) cost type, and let μ_t^0 be the prior probability of the type t of firm 1. In order to keep the model as simple as possible we assume that the transportation cost incurred by the firms are the same and equal to the distance times the delivered quantities. We suppose that $r > 1 + c$ so that any firm could supply any consumer and make a profit over variable costs (production + transportation) if it were in a monopoly position. We assume also that $c < \frac{1}{2}$ which implies that the second mover can always find a location so as to enjoy a positive share of the market and a positive profit gross of the fixed cost of entry, provided that firm 1 does not sell at prices lower than its total variable cost.

The above model is relatively standard in location theory except for the fact that it is the *first* location model to consider the entry preventing role of fixed costs under incomplete information. The specific modeling strategy used here is justified as follows. First, the second stage competition is assumed to be a Bertrand-like competition in delivered price schedules because in this way we can avoid the problem of the existence of an equilibrium in pure strategies, which would appear with competition in mill pricing (see d'Aspremont, Gabszewicz and Thisse (1979)). We can therefore concentrate on the analysis of the role of fixed costs in an incomplete information structure. Second, the particular incomplete information structure considered here, namely an informed incumbent at least as efficient as the uninformed entrant, corresponds to many observed situations such as those in which an incumbent firm may have acquired or not a cost advantage, through learning or experience, over an entrant. Finally, because of the information structure and the sequencing of moves, the location chosen by an established firm becomes a signal regarding that firms's costs. This signal may be used by the second mover to infer the type of the first mover, that is, whether or not firm 1 has acquired a cost advantage, which is a determining factor of the post-entry price schedule and of the entrant's profit. The other elements of the model are basically simplifying assumptions or standard features of location models.

Let us examine what happens in the case of complete information which will serve as a benchmark. We denote by $x_i \in [0, 1] \cup \{NE\} \equiv I$, firm i's decision at the first stage of the game, where $x_i \in [0, 1]$ means that firm i has chosen to enter the market and locate at a distance x_i from 0; $x_i = NE$ means that firm i has chosen not to enter. Let $p_i(x; x_1, x_2, t)$ be the price quoted by firm i to a consumer located at x when the first stage location decisions are x_1 and x_2 and the type of firm 1 is t. Since a firm which is out of the market cannot obviously compete in the second stage, we assume that $p_2(x; x_1, NE, t) > r$ for all $x \in [0, 1]$. Following Lederer and Hurter (1986), we assume that a consumer who is quoted the same price by both firms buys from the firm realizing the larger profit on his demand; if both firms realize the same profit on

that sale, he then buys from either one with some probability whose exact value has no effect on the equilibrium values. Following Hoover (1937) and the formal investigation by Lederer and Hurter (1986), it can be shown that under these assumptions the following price schedule constitutes the Nash equilibrium of the second stage subgame starting from (x_1, x_2):

$$
p_i(x, x_1, x_2; t) \begin{cases} = \max\{|\ x - x_1\ | + c, |\ x - x_2\ | + c\} & \text{if } t = h \text{ and } (x_1, x_2) \in [0,1]^2 \\ = \max\{|\ x - x_1\ |, |\ x - x_2\ | + c\} & \text{if } t = \ell \text{ and } (x_1, x_2) \in [0,1]^2 \\ = r & \text{if } x_i \in [0,1] \text{ and } x_j = NE \\ > r & \text{if } x_i = NE \end{cases} \tag{2.1}
$$

Without loss of generality, we can restrict our attention to the cases where $x_1 \in \left[0, \frac{1}{2}\right]$ since firm 2 will observe x_1 before deciding on x_2. Hence given spatial differentiation, the price equilibrium is such that the price quoted to a consumer located at x is the second-lowest serving cost over all firms. A formal discussion with the explicit subgame equilibrium profit functions is given in the Appendix. By backward induction we can now characterize the equilibrium location choices.

Under full information a location may be entry blockading for an incumbent only if the potential entrant incurs a sufficiently high fixed cost f. We assume that $f \in \left[\underline{f}(c), \overline{f}\right)$. The lower value $\underline{f}(c)$ is the upper bound of the fixed cost allowing the entrant to enter the market whatever the location and type of firm 1. If $f \leq \underline{f}(c)$ then whatever her location and whatever her type, an incumbent cannot deter entry and both types accommodate entry in full information equilibrium: facing the low cost incumbent, the entrant locates further away from the market center so that products are more differentiated than when firm 1 is a high cost incumbent. The analysis is then similar to the case with no fixed cost studied in Boyer, Laffont, Mahenc and Moreaux (1994, 1995). The higher value $\overline{f}$ is the lower bound of the fixed cost values allowing the high cost incumbent to blockade entry by simply locating at the market center. This is then the optimal location of both types. In addition, this location also minimizes the maximum attainable gross profit of a potential entrant. Hence for values higher than $\overline{f}$, entry is blockaded. When $f \in \left[\underline{f}(c), \overline{f}\right)$, the weaker incumbent can no longer blockade entry under full information. Realizing this, she locates away from the market center, at $x_1 = 2/5$ in equilibrium, and firm 2 enters and locates at $x_2 = 4/5$, that is, also away from the market center in order to soften price competition. The low cost incumbent can still blockade entry by locating at the market center. Hence, for f in this interval, entry is accommodated by the high cost incumbent whereas it is blockaded by the low cost incumbent when information is complete.

3 THE CASE OF INCOMPLETE INFORMATION: PRELIMINARY RESULTS

We expect the incumbent to modify her behavior when the potential entrant does not know exactly her unit costs. In such a situation of asymmetric information the incumbent's location may become a signal regarding her costs. As mentioned above, we concentrate on values of f belonging to the more interesting interval $\left(\underline{f}(c), \overline{f} \right]$ for which, under complete information, entry is blockaded by a low cost incumbent but accommodated by a high cost one. Since the type of firm 1 is revealed by assumption before the beginning of stage 2, the equilibrium price schedule is determined according to (2.1) in any subgame perfect equilibrium in which firm 2 is active. Hence we can concentrate on the first stage of the game.

3.1 Strategies and equilibria

A pure strategy of firm 1 is a mapping $\hat{x}_1 : T \to I_1$, where $I_1 \equiv \left[0, \frac{1}{2} \right]$. We will denote by $\hat{x}_1(t)$ the location selected by $\hat{x}_1$ for type t. A pure strategy of firm 2 is a mapping $\hat{x}_2 : I_1 \to I_2 \equiv \left[\frac{1}{2}, 1 \right] \cup \{NE\}$. We also need a family of conditional distributions giving, for each location decision of firm 1, the posterior probabilities on the types of firm 1 upon which firm 2 will base its own location decision. Let $\hat{\mu} : I_1 \to \mathcal{M}$ be the posterior mapping, where $\mathcal{M}$ is the set of probability distributions defined on T. We will denote by $\hat{\mu}_t(x_1)$ the probability assigned by firm 2 to type t given the observed location x_1.

A Perfect Bayesian Equilibrium (PBE) is a triplet $E^* \equiv \{\hat{x}_1^*, \hat{x}_2^*, \hat{\mu}^*\}$ such that:

(i) for $t = h, \ell :$ $\hat{x}_1^*(t) \in_{x_1 \in I_1} \Pi_1\left(x_1, \hat{x}_2^*(x_1), t\right)$

(ii) for any $x_1 \in I_1 :$ $\hat{x}_2^*(x_1) \in_{x_2 \in I_2} \sum_{t=h,\ell} \hat{\mu}_t^*(x_1) \Pi_2(x_1, x_2, t)$

(iii) for any $x_1 \in R\hat{x}_1^*$ (where Rz is the range of the function z): if Bayes's rule can be applied, $\hat{\mu}_t^*(x_1)$ is obtained from the prior μ^0 and firm 1's strategy via Bayes' rule; otherwise, $\hat{\mu}_t^*(x_1)$ is indeterminate.

Condition (i) requires that firm 1 of type t maximizes its profit given the strategy of firm 2. Condition (ii) requires that firm 2 maximizes its *expected* profit for any decision x_1 taken by firm 1, given the posterior belief $\hat{\mu}_t^*(x_1)$ based on the observation of firm 1's location. Condition (iii) requires that firm 2's posterior beliefs be consistent with the priors and firm 1's strategy if Bayes' rule can be applied, that is, if $x_1 \in \{\hat{x}_1^*(t) \mid t \in T\}$. The posteriors are indeterminate for out-of-equilibrium locations. We will denote by $\mathcal{E}$ the set of PBE. To simplify notation, we will

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denote by μ the posterior probability with which firm 2 is believing that firm 1 is of the low cost type.

Let $\tilde{x}_2 (x_1, \mu)$ be firm 2's best response after observing firm 1's decision x_1 with the posterior probability μ taken here as a parameter. Formally:

$$\tilde{x}_2 (x_1, \mu) \in_{x_2 \in I_2} \{\mu \Pi_2 (x_1, x_2, \ell) + (1 - \mu) \Pi_2 (x_1, x_2, h)\} \tag{3. 1}$$

Let $\dot{x}_1 (\mu, f)$ denote the incumbent's location for which the potential entrant, given his posterior belief, is indifferent between entering and staying out. Straightforward calculations give:

$$\dot{x}_1 (\mu, f) = \min \left\{ 1 - \mu c - \left[\frac{3}{4} \left(\mu^2 c^2 - \mu c^2 + 4f \right) \right]^{1/2}, \frac{1}{2} \right\}$$

Note that if firm 2 assumes that firm 1 is a high cost firm, then $\dot{x}_1 (0, f) = \frac{1}{2}$ since $1 - (3f)^{1/2}$ is strictly larger than $\frac{1}{2}$ for values of f smaller than $\overline{f}$. Thus there is no location at which the incumbent thwarts entry when the potential entrant believes her to incur the same variable cost as his own. By contrast, if firm 2 believes that the incumbent is a low cost firm, then $\dot{x}_1 (1, f) = 1 - c - (3f)^{1/2}$ which is smaller than $\frac{1}{2}$ for values of f larger than $\underline{f}(c)$. Thus any location close to the market center, belonging to the interval $\left(\dot{x}_1 (1, f), \frac{1}{2} \right]$ (respectively $\left(\dot{x}_1 (\mu, f), \frac{1}{2} \right]$), thwarts entry when firm 2 believes with probability 1 (respectively μ) that firm 1 incurs the same variable costs.

Let $\hat{\Pi}_1 (x_1, \mu, t) \equiv \Pi_1 (x_1, \tilde{x}_2 (x_1, \mu), t)$ be the profit of firm 1 of type t located at x_1, given that firm 2 chooses optimally its own location, believing with probability μ that firm 1 is of the low cost type.[§] The upper part of Figure 1 shows the profit function $\hat{\Pi}_1$ of the low cost incumbent as a function of x_1 for different values of μ. The lower part shows the profit function $\hat{\Pi}_1$ of the high cost incumbent. The functions are bivalued at $\dot{x}_1 (\mu, f)$ provided that the fixed cost f is sufficiently high, namely $f > \underline{f}(c)$. Figure 1 illustrates how crucial firm 2's conjecture regarding the incumbent's type is for its entry decision. If firm 1 chooses a location $x_1 \in \left[\dot{x}_1(1, f), \frac{1}{2} \right]$ then there exists a critical level of the posterior μ that we will denote $\dot{\mu} (x_1, f)$, such that firm 2 does not enter if $\mu > \dot{\mu} (x_1, f)$, is indifferent between entering or not if $\mu = \dot{\mu} (x_1, f)$, and enters if $\mu < \dot{\mu} (x_1, f)$. Finally, for any location $x_1 < \dot{x}_1 (1, f)$, firm 2 always enters the market whatever its posterior belief μ. Thus, for values of f in the range $\left(\underline{f}(c), \overline{f} \right]$, entry would be thwarted if

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[§] Defining $A (x_1, \mu, t) = \frac{1}{36} \left[-20x_1^2 + 8 (2 + \mu\theta_t + 3\theta_t) x_1 + (2 + \mu\theta_t)^2 + (12 + 6\mu + 9\theta_t) \theta_t \right]$ and $B (x_1, t) = r - \frac{1}{2} - \left(x_1^2 - x_1 \right)$, we obtain more explicitly:

$$\hat{\Pi}_1 (x_1, \mu, t) \begin{cases} = A (x_1, \mu, t) & \text{if } x_1 < \dot{x}_1 (\mu, f) \\ \in \{A (x_1, \mu, t), \ B (x_1, t)\} & \text{if } x_1 = \dot{x}_1 (\mu, f) \\ = B (x_1, t) & \text{otherwise} \end{cases}$$

and only if first, the observed location of firm 1 is close enough to the market center and second, the entrant expects with relatively high posterior probability that the incumbent is of the low cost type.

3.2 The limit probability function

The limit probability function and the intervals defined in this sub-section provide an easier description of the whole set of separating and pooling location equilibria. Since for out-of-equilibrium locations posterior beliefs are indeterminate, the limit probability function will help to characterize the range of posterior belief μ which would sustain a given equilibrium. Under the assumption $f < \overline{f}$, there exists a critical level of the posterior belief μ, strictly positive and denoted by μ^f, such that firm 2, observing $x_1 = \frac{1}{2}$, does not enter if $\mu > \mu^f$, enters if $\mu < \mu^f$ and is indifferent if $\mu = \mu^f$. For any $\mu \geq \mu^f$ we define $\dot{X}_1(\mu, f)$ as the interval $\left[\dot{x}_1(\mu, f), \frac{1}{2}\right]$ of firm 1's locations which thwart entry given the posterior belief μ.

For any $x_1 \in \dot{X}(\mu, f)$ we define $\dot{\mu}(x_1, f)$ as the smallest value of μ for which firm 2 does not enter if firm 1 is located at x_1. Note that if $\mu > \dot{\mu}(x_1, f)$, entry is strictly thwarted whereas if $\mu = \dot{\mu}(x_1, f)$, entry is weakly thwarted since firm 2 is indifferent between entering and not. Given f, the function $\dot{\mu}_1(x_1, f)$ is decreasing in x_1, from 1 at $x_1 = \dot{x}_1(1, f)$ to μ^f at $x_1 = \frac{1}{2}$. Also for a given x_1, the function $\dot{\mu}(x_1, f)$ is decreasing with f. Let us define:

- $X_1^W(x_1', \mu', t)$ as the set of locations which, whatever the posterior belief μ of firm 2, would be worse for firm 1 than x_1' with posterior μ'.

- $X_1^M(x_1', \mu', t)$ as the set of locations which result, for some posterior μ, in the same profit for firm 1 as (x_1', μ'), such that firm 2 is not indifferent between entering and not.

For any location x_1' and posterior belief μ' such that the market is attractive enough to the potential entrant,[¶] and for any location x_1, let us define the limit posterior probability function denoted by $\tilde{\mu}(x_1, x_1', \mu', t)$ as follows: if the posterior belief μ of firm 2 observing x_1 is higher than $\tilde{\mu}(\cdot)$, then it leads firm 1 of type t to switch from x_1' to x_1, that is $\mu > \tilde{\mu}(x_1, x_1', \mu', t) \Rightarrow \hat{\Pi}_1(x_1, \mu, t) > \hat{\Pi}_1(x_1', \mu', t)$. We obtain:

- for $x_1 \in X_1^M(x_1', \mu', t)$, $\tilde{\mu}(x_1, x_1', \mu', t)$ is the unique solution of $\hat{\Pi}_1(x_1, \mu, t) = \hat{\Pi}_1(x_1', \mu', t)$ since the $\hat{\Pi}_1(x_1, \mu, t)$ are parabolic functions;

[¶] Formally $\mu' \begin{cases} < \dot{\mu}(x_1', f), & \text{if } x_1' \in \dot{X}_1(1, f) \\ \in [0, 1], & \text{otherwise.} \end{cases}$

- for $x_1 \in X_1^W(x_1', \mu', t)$, $\tilde{\mu}(x_1, x_1', \mu', t) = 1$ since no conjecture based upon the location x_1 makes the deviation attractive;

- for any other x_1, $\tilde{\mu}(x_1, x_1', t) = \dot{\mu}(x_1, f)$ since any such x_1 allows the incumbent to prevent entry for values of the posterior belief in the interval $[\dot{\mu}(x_1, f), 1]$.

4   EQUILIBRIA

We first describe the set of separating equilibria and then the set of pooling equilibria. In a separating equilibrium, observing x_1 allows the value of t to be inferred exactly while the observation of x_1 in a pooling equilibrium gives no information. One could expect the same result as in Milgrom-Roberts' limit pricing analysis: "in any separating equilibrium entry takes place in exactly the same circumstances as if the entrant had been informed about the value of the incumbent's cost" (p. 448). However, in the present context, entry does not take place in a separating equilibrium in exactly the same circumstances as under full information. For values of $f \in \left(\underline{f}(c), \overline{f} \right]$, entry is blockaded by the low cost incumbent under full information while entry is accommodated by both types in any separating location equilibrium under incomplete information. Thus the low cost incumbent finds it more profitable to let the competitor whereas under complete information she would drive him out of the market. Such a striking result is obtained when firm 2, observing the incumbent choose to locate at the market center, does not put too much weight on firm 1 being the low cost type. If this were not so, the low cost incumbent would not find it attractive to reveal her type. Furthermore, the low cost incumbent cannot separate from her high cost counterpart at any location inside $\dot{X}(1, f)$, the set of locations close to the market center which deter entry provided that the entrant's beliefs are rather pessimistic (that is, concentrated on the low cost type). At any location in this set with $\mu = 1$, the high cost incumbent would find mimicry profitable since she could deter entry by being falsely identified. Therefore the separating equilibrium locations for the low cost incumbent must be outside $\dot{X}_1(1, f)$ and entry is thus accommodated.

In order to better understand the conditions under which there exist separating equilibria, let us consider Figure 1 where the profit functions $\hat{\Pi}_1(x_1, \mu, t)$, $\mu \in \{0, 1\}$, are plotted on the same diagrams for both types t of firm 1. Remember that in a separating equilibrium firm 1 discloses its type in choosing its location. Hence the equilibrium profit of the high cost type must lie on the $\hat{\Pi}_1(x_1, 0, h)$ curve. If so, the sole equilibrium location of this high cost type is the location maximizing $\hat{\Pi}(x_1, 0, h)$, denoted by $x_1^m(0, h)$. It is clear that the separating equilibrium location of the low cost type cannot lie in $X_1^M(x_1^m(0, h), 0, h) \cup \dot{X}_1(1, f)$ as defined in section 3.2, since then the high cost type would mimic the low cost type. The high cost type would be more profitable if it were located in these intervals and identified as a low cost firm, than

at $x_1^m(0,h)$ and rightly identified as the high cost type. Moreover, the low cost type cannot locate outside $X_1^M\left(x_1^m(0,\ell)0,\ell\right) \cup \dot{X}_1(1,f)$, for instance in the interval $[0,b]$ in Figure 1, since it would then be more profitable for the low cost firm 1 to deviate to $x_1^m(0,\ell)$ whatever the posterior of firm 2 observing $x_1^m(0,\ell)$. Defining $x_1^+\left(x_1,\mu,t\right)$ as $\sup\left\{x_1 \mid x_1 \in X_1^M\left(x_1,\mu,t\right)\right\}$, we thus find that the only possible locations for the low cost firm 1 are the locations in the interval $\left[x_1^+\left(x_1^m(0,h),0,h\right),\dot{x}_1(1,f)\right)$, that is, the interval $[a,\dot{x}_1(1,f))$ in the case of Figure 1. This interval is not empty for values of f lower than some $\tilde{f}$.[||]

Let x_1^{*h} and $x_1^{*\ell}$ be some locations satisfying all of the above constraints. Such locations can appear as separating equilibrium locations for firm 1 provided that the out-of-equilibrium posteriors do not lead either type of firm 1 to deviate, that is, provided that firm 2, observing a deviation, would assign a sufficiently high posterior probability to the high cost type. Hence the necessary and sufficient conditions such that x_1^{h*} and $x_1^{\ell*}$ are separating equilibrium locations are the following: the posterior beliefs function must satisfy conditions (4.1) and (4.2) below:

- for $x_1 \in \left\{x_1^{*h},x_1^{*\ell}\right\}$:

$$\hat{\mu}_h^*\left(x_1^{*h}\right) = 1 \text{ and } \hat{\mu}_\ell^*\left(x_1^{*\ell}\right) = 1 \tag{4. 1}$$

- for $x_1 \notin \left\{x_1^{*h},x_1^{*\ell}\right\}$:

$$\hat{\mu}_\ell^*\left(x_1\right) \begin{cases} \leq \dot{\mu}\left(x_1,f\right), & \text{if } x_1 \in \dot{X}_1(1,f) \\ \\ \leq \min\left\{\tilde{\mu}\left(x_1,x_1^{*h},0,h\right),\tilde{\mu}\left(x_1,x_1^{*\ell},1,\ell\right)\right\}, & \text{otherwise} \end{cases} \tag{4. 2}$$

In order for separating equilibria to exist, the following conditions on c and f must hold:[**]

$$x_1^+\left(x_1^m(0,h),0,h\right) \leq \frac{1}{2} \tag{4. 3}$$

$$f \leq \min\left\{\tilde{f},\overline{f}\right\} \tag{4. 4}$$

The set $\left(\underline{f}(c),\min\left\{\tilde{f},\overline{f}\right\}\right]$ is illustrated in Figure 2; it is non empty for $c \leq \overline{c}$.

Let us examine the different causes of non-existence of a separating equilibrium. First, if the fixed cost is sufficiently high $\left(f \geq \overline{f}\right)$ so that $\dot{x}_1(0,f) \leq \frac{1}{2}$, then locating at the market center is the best strategy for both types of firm 1, regardless of firm 2's posteriors beliefs. The type

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[||]Straightforward calculations give $\tilde{f} = \frac{3}{25}\left(1 - 2c - \left(c + \frac{1}{4}c^2\right)^{1/2}\right)^2$ which is plotted on Figure 2. Note that when $f \leq [\geq] \tilde{f}$, we have $a \leq [\geq] \dot{x}_1(1,f)$.

[**]In the particular context of this paper, (4.3) can be rewritten as $c \leq \overline{c}$ where $\overline{c} = \frac{9}{\sqrt{5}} - 4$. Moreover, it can be shown that $\tilde{f}(c)$ and $\underline{f}(c)$ intersect at $c = \overline{c}$.

of the firm is therefore not revealed. Second, if the gap c between the variable costs of the two types of firm 1 is too large, we have $\hat{\Pi}_1(\frac{1}{2}, 1, h) > \hat{\Pi}_1(x_1^m(0,h), 0, h)$. Thus even without fixed costs no separating equilibrium exists since there is no interval of locations where the low cost firm 1 could locate and be identified as such, without leading the high cost firm 1 to choose the same location. For sufficiently large values of the gap, the reaction of firm 2 observing any $x_1' \in \left(x_1^m(0,h), \frac{1}{2}\right)$ and believing that it faces a low cost firm 1, is to locate far enough from x_1' such that the high cost firm 1's profit at x_1' is higher than at $x_1^m(0,h)$, when it is rightly identified as the high cost type. Hence the self selection constraints cannot be satisfied (see Boyer, Laffont, Mahenc and Moreaux (1994, 1995) for details). A third cause comes from the interaction between the efficiency gap and the fixed cost when the efficiency gap is sufficiently small. With no fixed costs, separating equilibria would exist. But if the fixed cost of entry is high enough, $f > \tilde{f}$, then any location that would be a separating equilibrium location for the low cost firm 1 in the no fixed cost case, that is, $x_1 > a$, is indeed a monopoly position when the low cost type is rightly identified, that is $x_1 > \dot{x}_1(1, f)$. The separating equilibrium locations with no fixed cost are thus in $\dot{X}_1(1, f)$. Hence the high cost firm 1 would also enjoy a monopoly position if firm 2 believed it to be the low cost type. It would therefore mimic the low cost firm 1 since it then is more profitable than at $x_1^m(0,h)$ when rightly identified. We conclude:

Proposition 4.1 *Provided that f belongs to (c),, there exists a whole continuum of separating equilibria for sufficiently low values of the efficiency gap $(c \leq \overline{c})$ and of the fixed cost $f < \tilde{f}$. Both types of incumbent accommodate entry at such equilibrium locations so that:*

- *the high cost incumbent chooses the same location as she would under full information.*

- *the low cost incumbent moves away from the market center, which is the entry blockading equilibrium strategy under full information, namely: $x_1^{*\ell} < \dot{x}_1(1, f) < \frac{1}{2}$.*

One can interpret Proposition 1 as follows. Under asymmetric information, the low cost incumbent must incur a cost of separation due to a "non-optimal location". To be perfectly identified, she must give up a pooling monopoly position at the market center which is also her complete information equilibrium location. The signaling cost corresponds to the difference between her incomplete information separating equilibrium profit and her complete information equilibrium profit. The low cost incumbent needs to accommodate entry in order to disclose her information whereas entry would have been blockaded under full information. This a rather paradoxical result: given some appropriate conjectures (namely entrants' beliefs are not concentrated on the low cost type at locations close to the center), an incumbent may find it profitable to move away from her entry blockading complete information location so as to let a less efficient firm (the entrant) enter and enjoy a positive market share.

Let us now consider the pooling equilibria. In a pure strategy pooling equilibrium both types of firm 1 choose the same location so that, in observing this location, firm 2 obtains no additional information on the type of its competitor. The posteriors therefore take the same values as the priors. Let us denote by x_1^* a pooling equilibrium location. Let us remark first that $x_1 \in union_{t=h,\ell} X_1^W \left(x_1^m(0,t), 0, t \right)$ cannot be an equilibrium since at least one of the types of firm 1, say t', would earn higher profit at $x_1^m(0,t')$ whatever the posteriors of firm 2 observing x_1. Consider a location x_1^* outside $union_{t=h,\ell} X_1^W \left(x_1^m(0,t), 0, t \right)$. For this location to be a pooling equilibrium, two conditions must be satisfied by μ_ℓ^0: the high cost incumbent must find it profitable to mimic her low cost counterpart, and the latter must not be able to separate herself from the former:

$$\mu_\ell^0 \geq \max_{t=h,\ell} \tilde{\mu} \left(x_1^*, x_1^m(0,t), 0, t \right) \tag{4.5}$$

If (4.5) were not verified, we would have for some type t':

$$\hat{\Pi}_1^*(t') = \hat{\Pi}_1 \left(x_1^*, \mu^0, t' \right) < \hat{\Pi}_1 \left(x_1^m(0,t'), 0, t' \right)$$

and the implied type t' would be better at $x_1^m(0,t')$ whatever firm 2's beliefs observing $x_1^m(0,t')$. Such a location is supported as a pooling equilibrium by the posterior belief function:

$$\hat{\mu}_\ell^* (x_1) \begin{cases} \leq \dot{\mu}(x_1,f) & \text{for } x_1 \in \dot{X}_1(1,f) \\ = \mu_\ell^0 & \text{for } x_1 = x_1^* \\ \leq \min \left\{ \tilde{\mu} \left(x_1, x_1^*, \mu_\ell^0, h \right), \tilde{\mu} \left(x_1, x_1^*, \mu_\ell^0, \ell \right) \right\} & \text{otherwise} \end{cases} \tag{4.6}$$

There are two kinds of pooling equilibria depending on whether entry is accommodated or prevented.[††] Consider first a location x_1^* belonging to $\dot{X}_1(1,f)$ with $\mu_\ell^0 \geq \dot{\mu}(x_1^*,f)$. There exists some conjecture sustaining x_1^* as a pooling equilibrium. Firm 2's priors puts a sufficiently high weight on the low cost type that its high cost counterpart find it profitable to mimic it. Thus the high cost incumbent locates away from her full information entry accommodating location to successfully thwart entry under incomplete information. The high cost incumbent moves towards the market center[‡‡] such that observing x_1^* provides no information. Since the incumbent's location signals a low profitability of entry in equilibrium, a potential entrant prefers to stay out of the market. Such pooling equilibria result in less entry (the probability of entry

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[††]Note that, depending on the values of the efficiency gap c and the fixed cost f, the set of pooling equilibrium locations may be either connected for f sufficiently high, given c, as in the case of Figure 3 where the set of pooling is the interval $[b, \frac{1}{2}]$, or disconnected as in the case of Figure 1 where the set of pooling is given by the union of two intervals, namely $[b,a] \bigcup \dot{X}(1,f)$.

[‡‡]Straightforward calculations show that $x_1^m(0,h) < \dot{x}_1(1,f)$ is equivalent to $f < \frac{1}{3} \left(\frac{3}{5} - c \right)^2$, an inequality that is satisfied by any $f \in \left(\underline{f}(c), \overline{f} \right]$.

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is zero) than in the full information case where the probability of entry is μ_h^0, the probability or percentage of high cost incumbents in the market.

Another kind of pooling equilibrium exists where both types of the incumbent accommodate entry, namely any location outside $union_{t=h,\ell} X_1^W (x_1^m(0,t),0,t)$, when the prior and posterior beliefs satisfy (4.5) and (4.6) and $\mu_\ell^0 < \dot{\mu}(x_1^*,f)$ if x_1^* belongs to $\dot{X}_1(1,f)$. An interpretation of this result is that the decision of an established firm to locate close to the market center, whatever its type, may accommodate entry at equilibrium when the prior probability of the high cost incumbent (an incumbent no more efficient than the entrant) is high, and correspondingly, the profit from entering is sufficiently high to cover the fixed cost. The high cost incumbent would also accommodate entry in the full information case. However, in a context of asymmetric information, she finds it profitable to "quit" her full information equilibrium location to move towards the market center. Hence the high cost incumbent mimics her low cost counterpart's accommodating strategy because the entrant differentiates more than he would if he were fully informed. Therefore competition is relaxed in the delivered pricing competition subgame. By contrast, the low cost incumbent would have blockaded entry in the full information case. However, in the case of asymmetric information, the entrant's inference as to cost conditions encourages an entry accommodating strategy and discourages any deviation to a location where the low cost incumbent would be perfectly identified. Thus unlike the former kind of pooling equilibria, this kind involves more entry (the probability of entry is one) than in the full information case where it is again μ_h^0.

Proposition 4.2 *Any location outside* $_{t=h,\ell} X_1^W x_1^m(0,t),0,t$ *is a pure strategy pooling equilibrium if and only if prior beliefs satisfy requirement (4.5) and posterior beliefs satisfy requirement (4.6). A pooling equilibrium location* x_1^* *deters entry if* $\mu_\ell^0 \geq \dot{\mu} x_1^*,f$. *Otherwise, entry is accommodated in a pooling equilibrium.*

Note that there is no pooling equilibrium if the prior probability of a low cost incumbent is small, namely if $\mu_\ell^0 < \underline{\mu}_\ell^0$ where $\underline{\mu}_\ell^0$ denotes the lowest value taken by $\max_{t=h,\ell} \tilde{\mu}(x_1^*, x_1^m(0,t),0,t)$ over the candidate pooling locations x_1^*. It can be shown that $\underline{\mu}_\ell^0$ is strictly positive: from the definition of $\tilde{\mu}(x_1, x_1^m(0,t),0,t)$, we obtain that $\max_{t=h,\ell} \tilde{\mu}(x_1, x_1^m(0,t),0,t)$ is a continuous function with two local minima; one, the market center and the other, that location between $x_1^m(0,h)$ and $x_1^m(0,\ell)$ at which the functions $\tilde{\mu}(x_1, x_1^m(0,h),0,h)$ and $\tilde{\mu}(x_1, x_1^m(0,\ell),0,\ell)$ intersect, their values being strictly positive at both locations.

5 K-UNDEFEATED EQUILIBRIA

In the present model the action space of each player is continuous so that, as in most cases, there exists a continuum of PBE. Hence we need a refinement device. The now classical criteria, such as the intuitive criterion, the $D1$ criterion or the sequential perfectness criterion, do not restrict very efficiently the set of equilibria in the present context. But, as far as only pure strategy equilibria are concerned, we may resort to a new refinement in the spirit of the criterion recently proposed by Mailath, Okuno-Fujiwara and Postlewaite (1993). Consider two PBE: $E^* = \{\hat{x}_1^*, \hat{x}_2^*, \hat{\mu}^*\}$ and $E^{**} = \{\hat{x}_1^{**}, \hat{x}_2^{**}, \hat{\mu}^{**}\}$. Equilibrium E^* defeats equilibrium E^{**} if there exists first, an equilibrium location x_1^* in E^* (that is, $x_1^* \in \{\hat{x}_1^*(t), t \in T\}$) which is not an equilibrium location in E^{**} (that is, $x_1^* \notin \{x_1^{**}(t), t \in T\}$) and second, a subset of types $K \subseteq T$ such that:

(i) defining $\hat{\Pi}_1^*(t)$ and $\hat{\Pi}_1^{**}(t)$ as the equilibrium profits of type t in E^* and E^{**} respectively,

$$
\begin{aligned}
\hat{x}_1^*(t) &= x_1^* &&\forall t \in K \\
\hat{\Pi}_1^*(t) &\geq \hat{\Pi}_1^{**}(t) &&\forall t \in K \\
\hat{\Pi}_1^*(t) &> \hat{\Pi}_1^{**}(t) &&\text{for some type } t \in K
\end{aligned}
\tag{5. 1}
$$

(ii) for some $t \in K$:

$$
\mu_t^{**}(x_1^*) \neq \frac{\mu_t^0 \nu(t)}{\sum_{t' \in T} \mu_{t'}^0 \nu(t')}
\tag{5. 2}
$$

for any function $\nu(t) : T \to [0, 1]$ satisfying:

$$
\begin{aligned}
\left\{ t' \in K \text{ and } \hat{\Pi}_1^*(t') > \hat{\Pi}_1^{**}(t') \right\} &\Rightarrow \nu(t') = 1 \\
t' \notin K &\Rightarrow \nu(t') = 0.
\end{aligned}
$$

An equilibrium E^{**} is K-undefeated if no $E^* \in \mathcal{E}$ exists that defeats it. Intuitively, (paraphrasing Mailath et alii (1993)), one checks for *K-undefeatedness* of a proposed equilibrium E^{**} by considering a location x^* not chosen in E^{**} but chosen in an alternative equilibrium E^* by a subset $K \subseteq T$ of types of the first mover, for which the second equilibrium Pareto dominates the first one in the sense of condition (i). *K-undefeatedness* requires that the second mover's updated beliefs at that location x^* in the original equilibrium be consistent with the existence of such a subset K, in the sense of condition (ii) [for all $t \in K : \hat{\mu}_t^{**}(x_1^*) = (\mu_t^0 \nu(t) / \sum_{t' \in T} \mu_{t'}^0 \nu(t'))$]. If the beliefs which support the original equilibrium are not consistent in this way, then the second equilibrium is said to defeat the proposed equilibrium. This is a modified version of undefeatedness as proposed by Mailath, Okuno-Fujiwara and Postlewaite in that we split the set of sender's types in two subsets: the subset K of types which prefer the alternative equilibrium to the proposed equilibrium, and the complementary subset. The idea is that not every type that

sends one signal does at least as well to send a second signal. Howeveer, some types distinguish themselves in that they have an incentive to send a second signal. Thus we require that only these types actually send a second signal.

According to the values of the cost discrepancies and the priors there may exist either only separating equilibria, only pooling equilibria, or both. We examine these three cases in succession.

5.1   Only separating equilibria exist

Pooling may not occur if the prior probability of low cost is too small − so small that high cost incumbents find it unprofitable to masquerade as low cost ones − namely if $\mu_\ell^0 < \underline{\mu}_\ell^0$. In this case, only the Riley equilibrium, that is, the separating equilibrium with the least amount of inefficient signaling, is K-undefeated. Consider two separating equilibria $\left\{ x_1^m(0,h), x_1^{*\ell} \right\}$ and $\left\{ x_1^m(0,h), x_1^{*'\ell} \right\}$ with $x_1^{*'\ell} < x_1^{*\ell}$; let us show that $x_1^{*'\ell}$ defeats $x_1^{*\ell}$. Since $\hat{\Pi}_1 \left(x_1^{*'\ell}, 1, \ell \right) > \hat{\Pi}_1^* \left(x_1^{*\ell}, 1, \ell \right)$ (see Figure 1), then $K = \{\ell\}$. The equilibrium $\left\{ x_1^m(0,h), x_1^{*\ell} \right\}$ is sustained by posteriors $\hat{\mu}_\ell^* \left(x_1^{*'\ell} \right) \le \min \left\{ \tilde{\mu} \left(x_1^{*'\ell}, x_1^{*\ell}, 1, \ell \right), \tilde{\mu} \left(x_1^{*'\ell}, x_1^m(0,h), 0, h \right) \right\} < 1$. Since $\nu(\ell) = 1$ and $\nu(h) = 0$, then $\left[\mu_\ell^0 \nu(\ell) / \sum_{t \in T} \mu_t^0 \nu(t) \right] = 1 \; \ne \hat{\mu}_\ell^* \left(x_1^{*'\ell} \right)$, that is, (5.2) is satisfied. Thus the only separating equilibrium which cannot be defeated is the Riley equilibrium, that is, the least distorting separating equilibrium. We will denote by $x_1^{*\ell,R}$ the Riley equilibrium location of the low cost type firm 1: $x_1^{*\ell,R} = \inf \left\{ x_1^{*\ell} \mid \left\{ x_1^m(0,h), x_1^\ell(0,h), x_1^{*\ell} \right\} \in \mathcal{S} \right\}$ where $\mathcal{S}$ is the set of separating equilibria.

5.2   Only pooling equilibria exist

According to the value of the prior μ_ℓ^0, the market center may or may not be a pooling equilibrium where entry by firm 2 is blockaded. Suppose first that $\mu_\ell^0 \ge \mu^f$ so that $x_1 = \frac{1}{2}$ is a pooling equilibrium where firm 2 does not enter (recall that $\mu^f = \dot{\mu} \left(\frac{1}{2}, f \right)$, see section 3.2 above). Let us show that it is the only K-undefeated equilibrium. Let $x_1^* < \frac{1}{2}$ be another pooling equilibrium. For each type $t \in T$, $\hat{\Pi}_1 \left(\frac{1}{2}, \mu_\ell^0, t \right) > \hat{\Pi}_1 \left(x_1^*, \mu_\ell^0, t \right)$ so that $K = T$. The equilibrium location x_1^* is sustained by posteriors satisfying $\hat{\mu}_\ell^* \left(\frac{1}{2} \right) \le \mu^f$, hence $\hat{\mu}_\ell^* \left(\frac{1}{2} \right) \le \mu_\ell^0$. Since both types of firm 1 earn higher profits at $\frac{1}{2}$ than at x_1^*, then $K = \{h, \ell\}$, and $\nu(t) = 1 \; \forall t \in T$, such that

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Mailath et alii (1993) set forth that the subset K includes all the types t such that $\hat{x}_1^*(t) = x_1^*$. But taking K as the maximum set of types sending x_1^* severely restricts the refinement power of the criterion as far as pooling equilibria are concerned. The marginal change we bring to the concept of undefeated equilibrium appears also in a refinement concept proposed by Umbhauer (1991), the consistent forward equilibrium refinement. Both the criterion of Mailath et alii and that of Umbhauer interpret disequilibrium messages as signals and remove implausible equilibria by using the logic of forward induction.

$[\mu_t^0 \nu(t) / \sum_{t' \in T} \mu_{t'}^0 \nu(t')] = \mu_t^0$. Hence first, if $\mu_\ell^0 > \mu^f$, then (5.2) is satisfied and second, if $\mu_\ell^0 = \mu^f$, then (5.2) is satisfied provided that the posteriors sustaining $x_1^*, \hat{\mu}_\ell^* \left(\frac{1}{2}\right)$ are strictly less than μ_ℓ^0.

Suppose now that $\mu_\ell^0 < \mu^f$, so that, for any location x_1, if $\hat{\mu}_\ell(x_1) = \mu_\ell^0$ then firm 2 enters the market. In this case the two functions $\hat{\Pi}_1 (x_1, \mu_\ell^0, t), t \in T$, are strictly concave and maximized at different locations $x_1^m (\mu_\ell^0, t), t \in T$. Let us define $x_1^p (\mu_\ell^0, t)$ as follows:

$$x_1^p \left(\mu_\ell^0, t \right) \in \left\{ \hat{\Pi}_1 \left(x_1, \mu^0, t \right) \mid x_1 \text{ satisfies (5.4) and (5.5)} \right\} \tag{5. 3}$$

$$x_1 \in \frac{1}{2} \backslash union_{t=h,\ell} \underline{X}_1 \left(x_1^m(0, t'), 0, t' \right) \tag{5. 4}$$

$$\tilde{\mu} \left(x_1, x_1^m(0, t'), 0, t' \right) \leq \mu_\ell^0 \qquad t' \in T \tag{5. 5}$$

The location $x_1^p (\mu_\ell^0, t)$ is the pooling location which maximizes type t's profit amongst all the locations which may appear as pooling locations given the prior μ_ℓ^0. For all the admissible values of the variable cost discrepancy c, we have $x_1^p (\mu_\ell^0, h) \leq x_1^p (\mu_\ell^0, \ell)$.

First, consider the pooling locations x_1^* such that either $x_1^* < x_1^p (\mu_\ell^0, h)$ or $x_1^* > x_1^p (\mu_\ell^0, \ell)$. For any such location there exists another pooling, which we will denote by $x_1^{*'}$, for which $\hat{\Pi}_1 \left(x_1^{*'}, \mu_\ell^0, t \right) > \hat{\Pi}_1 (x_1^*, \mu_\ell^0, t), t \in T$: if $x_1^* < x_1^p (\mu_\ell^0, h)$ then choose an $x_1^{*'} \in (x_1^*, x_1^p (\mu_\ell^0, h))$ and if $x_1^* > x_1^p (\mu_\ell^0, \ell)$ then choose an $x_1^{*'} \in (x_1^p (\mu_\ell^0, \ell), x_1^*)$. In this case $K = T$ and the equilibrium x_1^* is sustained by out-of-equilibrium beliefs $\hat{\mu}_\ell^* \left(x_1^{*'} \right) \leq \min \left\{ \tilde{\mu} \left(x_1^{*'}, x_1^*, \mu_\ell^0, t \right), t \in T \right\} < \mu_\ell^0$, the second inequality being implied by $\hat{\Pi}_1 \left(x_1^{*'}, \mu_\ell^0, t \right) > \hat{\Pi}_1 (x_1^*, \mu_\ell^0, t), t \in T$. Since both firms are more profitable at $x_1^{*'}$, then $\nu(t) = 1, t \in T$, so that $[\mu_t^0 \nu(t) / \sum_{t' \in T} \mu_{t'}^0 \nu(t')] = \mu_\ell^0 \neq \hat{\mu}_t^* \left(x_1^{*'} \right)$, that is, (5.2) is satisfied. We conclude that any pooling x_1^* such that either $x_1^* < x_1^p (\mu_\ell^0, h)$ or $x_1^* > x_1^p (\mu_\ell^0, \ell)$ is defeated.

Second, consider the pooling equilibrium locations $x_1^* \in [x_1^p (\mu_\ell^0, h), x_1^p (\mu_\ell^0, \ell))$ and take any other pooling $x_1^{*'} \in (x_1^*, x_1^p (\mu_\ell^0, \ell))$. For such a location we have $\hat{\Pi}_1 \left(x_1^{*'}, \mu_\ell^0, \ell \right) > \hat{\Pi}_1 (x_1^*, \mu_\ell^0, \ell)$ and $\hat{\Pi}_1 \left(x_1^{*'}, \mu_\ell^0, h \right) < \hat{\Pi}_1 (x_1^*, \mu_\ell^0, h)$ so that $K = \{\ell\}$. For x_1^* to be an equilibrium it must be sustained by posteriors $\hat{\mu}_\ell^* (x_1^*) < \mu_\ell^0$. The function ν is in the present case: $\nu(\ell) = 1$ and $\nu(h) = 0$, hence $[\mu_\ell^0 \nu(\ell) / \sum_{t \in T} \mu_t^0 \nu(t)] = 1 > \hat{\mu}_\ell^* \left(x_\ell^{*'} \right)$ and (5.2) is satisfied. We conclude that all the pooling under consideration are defeated.

Third, consider the pooling location $x_1^* = x_1^p (\mu_\ell^0, \ell)$. The only other pooling locations which could possibly defeat $x_1^p (\mu_\ell^0, \ell)$ are pooling locations $x_1^{*'}$ in the interval $\left(x_1^- (x_1^p (\mu_\ell^0, \ell), \mu_\ell^0, \ell), x_1^p (\mu_\ell^0, \ell) \right)$, where for any x_1, μ and $t, x_1^- (x_1, \mu, t)$ is defined as $\inf \{ x_1' \mid x_1' \in X_1 (x_1, \mu, t) \}$. In such pooling locations $x_1^{*'}$ the high cost type is more profitable than at $x_1^p (\mu_\ell^0, \ell)$, and the low

Were K be defined as $\{\ell, h\}$, as in Mailath et alii (1993), we could not eliminate those locations.

cost type, less profitable. Since $[x_1^p(\mu_\ell^0, h), x_1^p(\mu_\ell^0, \ell)) \subseteq \left(x_1^-\left(x_1^p(\mu_\ell^0, \ell), \mu_\ell^0, h\right), x_1^p(\mu_\ell^0, \ell)\right)$, such pooling locations $x_1^{*'}$ exist. The equilibrium $x_1^p(\mu_\ell^0, \ell)$ is sustained by any out-of-equilibrium beliefs $\hat{\mu}_\ell^*\left(x_1^{*'}\right) \leq \min\left\{\tilde{\mu}\left(x_1^{*'}, x_1^p(\mu_\ell^0, \ell), \mu_\ell^0, t\right), \ t \in T\right\}$, one of which is $\hat{\mu}_\ell^*\left(x_1^{*'}\right) = 0$, that is, $\hat{\mu}_h^*\left(x_1^{*'}\right) = 1$. However, there exists a whole range of posteriors each of which works as well, namely $\hat{\mu}_h^*\left(x_1^{*'}\right) \in \left(\max\left\{\tilde{\mu}\left(x_1^{*'}, x_1^p(\mu_\ell^0, \ell), \mu_\ell^0, t\right), \ t \in T\right\}, 1\right)$. The set K is equal to $\{h\}$ and the functions ν takes the following values: $\nu(h) = 1$ and $\nu(\ell) = 0$, so that $\left[\mu_h^0 \nu(h)/\sum_{t \in T}\mu_t^0 \nu(t)\right]$ $= 1$. We conclude that $x_1^* = x_1^p(\mu_\ell^0, \ell)$ is K-undefeated iff sustained by out-of-equilibrium beliefs $\hat{\mu}_h^*\left(x_1^{*'}\right) = 1$ for any $x_1^{*'}$ which satisfies (5.4), (5.5) with a strict inequality rather than a weak one, and $x_1^{*'} < x_1^p(\mu_\ell^0, \ell)$.

5.3   Both separating and pooling equilibria exist

If $\mu_\ell^0 \geq \mu^f$, then $x_1 = \frac{1}{2}$ is a pooling equilibrium location which results for each type of firm 1 in higher profits than any other equilibrium location, either pooling or separating. The analysis is quite similar to the analysis conducted in the above subsection 5.2 (first paragraph) since the posteriors sustaining any equilibrium other than $\frac{1}{2}$ must satisfy $\hat{\mu}_\ell^*\left(\frac{1}{2}\right) \leq \mu^f$. Hence the conclusion is the same: $\frac{1}{2}$ is the only K-undefeated equilibrium if either $\mu_\ell^0 > \mu^f$, or $\mu_\ell^0 = \mu^f$ and the posteriors sustaining any other equilibrium are such that $\hat{\mu}_\ell^*\left(\frac{1}{2}\right) < \mu_\ell^0$.

Suppose now that $\mu_\ell^0 < \mu^f$ so that firm 2 enters the market in both pooling and separating equilibria. All the defeating relations between separating equilibria are the same as those we examined in subsection 5.1. Hence it only remains to compare the Riley equilibrium to the pooling equilibrium $x_1^* = x_1^p(\mu_\ell^0, \ell)$ supported by posteriors $\hat{\mu}_h^*(x_1') = 1$ for any location $x_1' < x_1^*$ which may appear as a pooling equilibrium location.

First, suppose that $\hat{\Pi}_1\left(x_1^p(\mu_\ell^0, \ell), \mu_\ell^0, \ell\right) < \hat{\Pi}_1\left(x_1^{*\ell,R}, 1, \ell\right)$. Let us first show that the Riley equilibrium defeats the pooling. The pooling is sustained by posteriors $\hat{\mu}_\ell^*\left(x_1^{*\ell,R}\right) < 1$. Since $K = \{\ell\}$, then $\nu(\ell) = 1$ and $\nu(h) = 0$ so that $\left[\mu_\ell^0 \nu(\ell)/\sum_{t \in T}\mu_t^0 \nu(t)\right] = 1$, that is, (5.2) is satisfied. The same argument shows that no pooling can defeat the Riley equilibrium (the low cost type would lose if it sent a pooling signal). We conclude that in this case the Riley equilibrium is the only K-undefeated equilibrium.

Second, suppose that $\hat{\Pi}_1\left(x_1^p(\mu_\ell^0, \ell), \mu_\ell^0, \ell\right) > \hat{\Pi}_1\left(x_1^{*\ell,R}, 1, \ell\right)$ and let us show that the pooling defeats the Riley equilibrium. Note that by assumption $\mu_\ell^0 > \tilde{\mu}\left(x_1^p(\mu_\ell^0, \ell), x_1^{*\ell,R}, 1, \ell\right)$, and the Riley equilibrium is sustained by posteriors $\hat{\mu}_\ell^*\left(x_1^p(\mu_\ell^0, \ell)\right) \leq \tilde{\mu}\left(x_1^p(\mu_\ell^0, \ell), x_1^{*\ell,R}, 1, \ell\right)$. Also $\hat{\Pi}_1\left(x_1^p(\mu_\ell^0, \ell), \mu_\ell^0, \ell\right) \geq \hat{\Pi}_1\left(x_1^m(0, h), 0, h\right)$ since $x_1^p(\mu_\ell^0, \ell)$ is a pooling equilibrium, thus $K = \{h, \ell\}$. First, if the high cost type earns strictly higher profits in the pooling equilibrium, then

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$\nu(h) = 1 = \nu(\ell)$; therefore $[\mu_\ell^0 \nu(\ell)/\sum_{t \in T} \mu_t^0 \nu(t)] = \mu_\ell^0 > \mu_\ell^* (x_1^p (\mu_\ell^0, \ell))$ implying that (5.2) is satisfied and the Riley equilibrium is defeated.

Third, suppose that $\hat{\Pi}_1 (x_1^p (\mu_\ell^0, \ell), \mu_\ell^0, \ell) = \hat{\Pi}_1 (x_1^{*\ell,R}, 1, \ell)$. Let us show that the two equilibria remain K-undefeated. The only type that could be induced to deviate from equilibrium is the high cost type which would prefer the pooling iff $\hat{\Pi}_1 (x_1^p (\mu_\ell^0, \ell), \mu_\ell^0, h) > \hat{\Pi}_1 (x_1^m(0, h), 0, h)$, which is necessarily satisfied. In this case, $K = \{h, \ell\}$. The Riley equilibrium is sustained by posteriors $\hat{\mu}_\ell^* (x_1^p (\mu_\ell^0, \ell)) \leq \tilde{\mu} (x_1^p (\mu_\ell^0, \ell), x_1^m(0, h), 0, h) < \mu_\ell^0$, that is, $\hat{\mu}_h^* (x_1^p (\mu_\ell^0, \ell)) > \mu_h^0$. In the present case, $\nu(h) = 1$ and $\nu(\ell) \in [0, 1]$, therefore we have $[\mu_h^0 \nu(h)/\sum_{t \in T} \mu_t^0 \nu(t)] \in [\mu_h^0, 1]$. Thus there exists some value of $\nu(\ell)$ such that $[\mu_h^0 \nu(h)/\sum_{t \in T} \mu_t^0 \nu(t)] = \hat{\mu}_h^* (x_1^p (\mu_\ell^0, \ell))$. Since the same argument applies to the other type ℓ, then (5.2) is not satisfied. Clearly each equilibrium remains K-undefeated by the other one when $\hat{\Pi}_1 (x_1^p (\mu_\ell^0, \ell), \mu_\ell^0, h) = \hat{\Pi}_1 (x_1^m(0, h), 0, h)$. Lastly, the pooling cannot be defeated by another separating equilibrium nor the Riley equilibrium defeated by another pooling.

We recapitulate as follows:

Proposition 5.1 *When f belongs to (c), and c belongs to $0, \frac{1}{2}$, the complete information equilibrium calls for the low cost incumbent to blockade entry by locating at the market center and for the high cost incumbent to accomodate entry; however, under incomplete information:*

- *if $f < \tilde{f}$ and $c \leq \overline{c}$:*
    - *for any $\mu_\ell^0 \in \mu^f, 1$, both pooling and separating equilibria exist and the unique K-undefeated equilibrium calls for both types of incumbent to pool at the market center and for the entrant to stay out. Thus entry is blockaded by the high cost incumbent;*
    - *for any $\mu_\ell^0 \in \underline{\mu}_\ell^0, \mu^f$, both pooling and separating equilibria exist and the unique K-undefeated equilibrium is such that either both types of incumbent accommodate entry with $x_1^{*h} = x_1^m(0, h)$ and $x_1^{*\ell} = x_1^{*\ell,R}$, or both types deter entry with $x_1^{*h} = x_1^{*\ell} = x_1^p \mu_\ell^0, \ell$, depending on which of the two equilibrium outcomes results in more profit for the low cost incumbent;*
    - *for any $\mu_\ell^0 \in 0, \underline{\mu}_\ell^0$, only separating equilibria exist and the unique K-undefeated equilibrium is such that both types of incumbent accommodate entry with $x_1^{*h} = x_1^m(0, h)$ and $x_1^{*\ell} = x_1^{*\ell,R}$.*
- *Otherwise, only pooling equilibria exist and*
    - *for any $\mu_\ell^0 \in \mu^f, 1$, the unique K-undefeated equilibrium calls for both types of incumbent to pool at the market center. Entry is blockaded.*

– for any $\mu_\ell^0 \in {0, \mu^f}$, the unique K-undefeated equilibrium calls for both types of incumbent to pool at $x_1^p{\mu_\ell^0, \ell}$ sustained by posterior beliefs concentrated on the high cost type for any other location to the left of $x_1^p{\mu_\ell^0, \ell}$. Entry is accommodated.

When prior beliefs are such that μ_ℓ^0 is sufficiently high (that is, the entrant expects a priori that the incumbent is a low cost one), the market center emerges not only as an entry blockading strategy for the high cost incumbent but also as the unique K-undefeated equilibrium. Thus the entrant prefers staying out even if the incumbent is no more efficient. As there is less entry than under full information, the entry blockading behavior is damaging for social welfare and might be discouraged by public policy.

More disturbing is the case in which prior beliefs are such that μ_ℓ^0 is rather small. For values of the fixed cost no higher than $\tilde{f}$, and values of the variable cost lower than $\overline{c}$, the least cost separating equilibrium is the only plausible equilibrium. Thus the low cost incumbent finds it profitable to accommodate entry when a potential entrant is not a priori perfectly informed about her efficiency. Recall that this type of incumbent would actually blockade entry at the market center were information complete. Not only is the potential entrant uncertain about the efficiency of the established firm but he also believes, for some exogenous reason, with such low probability that a low cost incumbent is likely to be observed at the market center that, if such an observation was made, he will enter the market and compete. This conjecture gives the low cost incumbent a strong incentive to disclose information. Thus entry is accommodated.

For other values of fixed and variable costs, low values of μ_ℓ^0 also lead the low cost incumbent to give up her full information equilibrium location at the market center and accommodate entry. The entrant however does not learn the true cost of his competitor. The characteristics of the technology, that is, the values of fixed and variable costs, are such that no separating equilibrium exists. Hence the incumbent cannot disclose information on her true cost whatever her type. Nevertheless, the low cost incumbent finds it profitable to give up her full information equilibrium location at the market center and share the market, since the entrant puts sufficient weight on the probability of the incumbent being the high cost type. Thus entry will not be thwarted if this location is observed. Although the threat of entry is based on the overestimation of the efficient incumbent's cost, there is nothing an incumbent can do to correct the entrant's conjecture. Thus locating away from the market center allows the low cost incumbent to relax price competition by increasing product differentiation.

6 CONCLUSION

In reaction to Schmalensee (1978), some economic theorists have argued that there may be better entry preventing strategies than product proliferation. Either product specification is more profitable in some cases (Bonanno 1987), or the incumbent may not incur sufficiently high exit costs to credibly deter entry by crowding the product spectrum (Judd (1985)). However, little attention has been paid to entry blockading behavior in spatial or product differentiation competition. We have stressed the importance of such behavior in the context of incomplete information. If the potential entrant is not perfectly informed about the incumbent's costs, pre-entry product specification may rationally be read as a signal regarding these costs. Hence, beliefs are of great relevance in the emergence of entry blockading strategies. We have considered a market that under full information would be monopolized by a low cost incumbent who blockades entry by locating at the market center, but would not be monopolized by a high cost incumbent. Under incomplete information, if a priori the potential entrant expects the incumbent to be of the low cost type, the market center becomes a plausible location from which a high cost incumbent blockades entry. On the other hand, if a priori the entrant expects the incumbent to be a high cost type with a high probability, entry will occur regardless of the incumbent's cost. The low cost incumbent then find it more profitable to abandon her full information location at the market center, thus accommodating entry. She moves away from the market center so as to either find a location where she can credibly disclose information on her true costs, or if mimicry from a high cost incumbent cannot be prevented, relax price competition through more product differentiation.

APPENDIX

Given the equilibrium price schedule (2.1), the subgame (full information) equilibrium profits are given by the following expressions, where $\theta_h = c$ and $\theta_\ell = 0$, if both firms are present in the market, that is, for any $x_1 \in \left[0, \frac{1}{2}\right]$ and $x_2 \in (x_1, 1]$,

$$\Pi_1(x_1, x_2, t) = \left(\frac{1}{2}x_2\right)^2 - 3\left(\frac{1}{2}x_1\right)^2 + \frac{1}{2}x_1x_2 + \frac{1}{2}\theta_t(x_1 + x_2) + \left(\frac{1}{2}\theta_t\right)^2$$

$$\Pi_2(x_1, x_2, t) = \left(\frac{1}{2}x_1\right)^2 - 3\left(\frac{1}{2}x_2\right)^2 + \frac{1}{2}x_1x_2 + (x_2 - x_1) + \frac{1}{2}\theta_t(x_1 + x_2) - \theta_t + \left(\frac{1}{2}\theta_t\right)^2 - f,$$

and if firm 2 stays out, that is, for any $x_1 \in \left[0, \frac{1}{2}\right]$ and $x_2 = NE$,

$$\Pi_1(x_1, NE, t) = r - \frac{1}{2} - (c - \theta_t) - (x_1^2 - x_1)$$

$$\Pi_2(x_1, NE, t) = 0.$$

If firm 2 enters the market, its location will be given by its best reply function:

$$x_2 = \frac{1}{3}(x_1 + 2 + \theta_t) \quad \text{for any } x_1 \in \left[0, \frac{1}{2}\right]$$

so that its profit will amount to:

$$\Pi_2 = \frac{1}{3}(x_1 - 1 + \theta_t)^2 - f.$$

We conclude from the last formula the following. For $f < \frac{1}{3}\left(\frac{1}{2} - \theta_t\right)^2$, whatever the location it chooses, firm 1 cannot blockade firm 2's entry. Let us denote $\underline{f}(c) = \frac{1}{3}\left(\frac{1}{2} - c\right)^2$ and $\overline{f} = \frac{1}{12}$. In this case, the optimal decision of firm 1 of type t is to locate at $x_1(t) = \min\left\{\frac{1}{5}(4\theta_t + 2), \frac{1}{2}\right\}$ for $t = h, \ell$, so that the equilibrium locations and profits are given as functions of f and t as follows :

(i) If $f < \frac{1}{3}\left(\frac{1}{2} - \theta_t\right)^2$ and $\theta_t < \frac{1}{8}$, then

$$x_1^*(t) = \frac{1}{5}(2 + 4\theta_t), \quad \Pi_1^*(t) = \frac{1}{5}(1 + 2\theta_t)^2$$

$$x_2^*(t) = \frac{1}{5}(4 + 3\theta_t), \quad \Pi_2^*(t) = \frac{3}{25} + \left(\frac{3}{5}\right)^2(2\theta_t + 3\theta_t^2) - f$$

(ii) If $f < \frac{1}{3}\left(\frac{1}{2} - \theta_t\right)^2$ and $\theta_t \in \left[\frac{1}{8}, \frac{1}{2}\right)$, then

$$x_1^*(t) = \frac{1}{2}, \qquad \Pi_1^*(t) = \frac{7}{36} + \frac{4}{9}(\theta_t^2 + 2\theta_t)$$

$$x_2^*(t) = \frac{1}{6}(5 + 2\theta_t), \quad \Pi_2^*(t) = \frac{1}{12} + \frac{1}{3}(\theta_t + \theta_t^2) - f$$

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For $f \in \left[\frac{1}{3} \left(\frac{1}{2} - \theta_t \right)^2, \frac{1}{3} (1 - \theta_t)^2 \right]$, firm 1 could either share the market by choosing $x_1 \in \left[0, 1 - \theta_t - (3f)^{1/2} \right)$ (respectively $x_1 \in \left[0, 1 - \theta_t - (3f)^{1/2} \right]$), or blockade entry by locating at $x_1 \in \left[1 - \theta_t - (3f)^{1/2}, \frac{1}{2} \right]$ (respectively $x_1 \in \left(1 - \theta_t - (3f)^{1/2}, \frac{1}{2} \right]$ if firm 2 chooses not to enter when indifferent (respectively chooses to enter when indifferent). Obviously, it is better for firm 1 to blockade entry and locate at $x_1 = \frac{1}{2}$ where the monopoly profit is maximized. For $f > \frac{1}{3} (1 - \theta_t)^2$, firm 2 never enters regardless of the location of firm 1. Therefore:

(iii) If $f = \frac{1}{3} \left(\frac{1}{2} - \theta_t \right)^2$, there are two equilibria: the first one the same as in the previous case (i), the second one given by

$$x_1^*(t) = \tfrac{1}{2}, \qquad \Pi_1^*(t) = r - \tfrac{1}{4} - (c - \theta_t)$$

$$x_2^*(t) = NE, \quad \Pi_2^*(t) = 0$$

(iv) If $f > \frac{1}{3} \left(\frac{1}{2} - \theta_t \right)^2$, there is only one equilibrium where firm 1 blockades entry at the market center.

Note that when the fixed cost of the second mover is high enough but not too high, that is $f \in \left(\frac{1}{3} \left(\frac{1}{2} - \theta_t \right)^2, \frac{1}{3} (1 - \theta_t)^2 \right)$, there exists a whole range of entry blockading locations in the neighborhood of the market center. This range, equal to $\left[1 - \theta_t - (3f)^{1/2}, \frac{1}{2} \right]$, is an increasing function of the variable cost gap between the two firms, and of the entrant's fixed cost. For such values of the fixed cost, the incumbent's location is not driven by product differentiation purposes as is usually the case in spatial competition models. The classic conflict in the determination of the equilibrium differentiation, a greater market share versus more drastic price competition when locating nearer the market center, disappears (see Anderson (1987) for an analysis of Stackelberg spatial competition conducted in terms of mill prices rather than of delivered prices as in the present paper). The only remaining strategic effects are first, the incentive to drive the rival out of the market and second, the maximization of the monopoly profit. Both effects work in the same direction, that is, towards the market center.

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FIGURE 1

SEPARATING EQUILIBRIUM LOCATIONS : $[a, \dot{x}_1(1, f))$

POOLING EQUILIBRIUM LOCATIONS : disconnected set $[b, a] \cup \dot{X}(1, f)$

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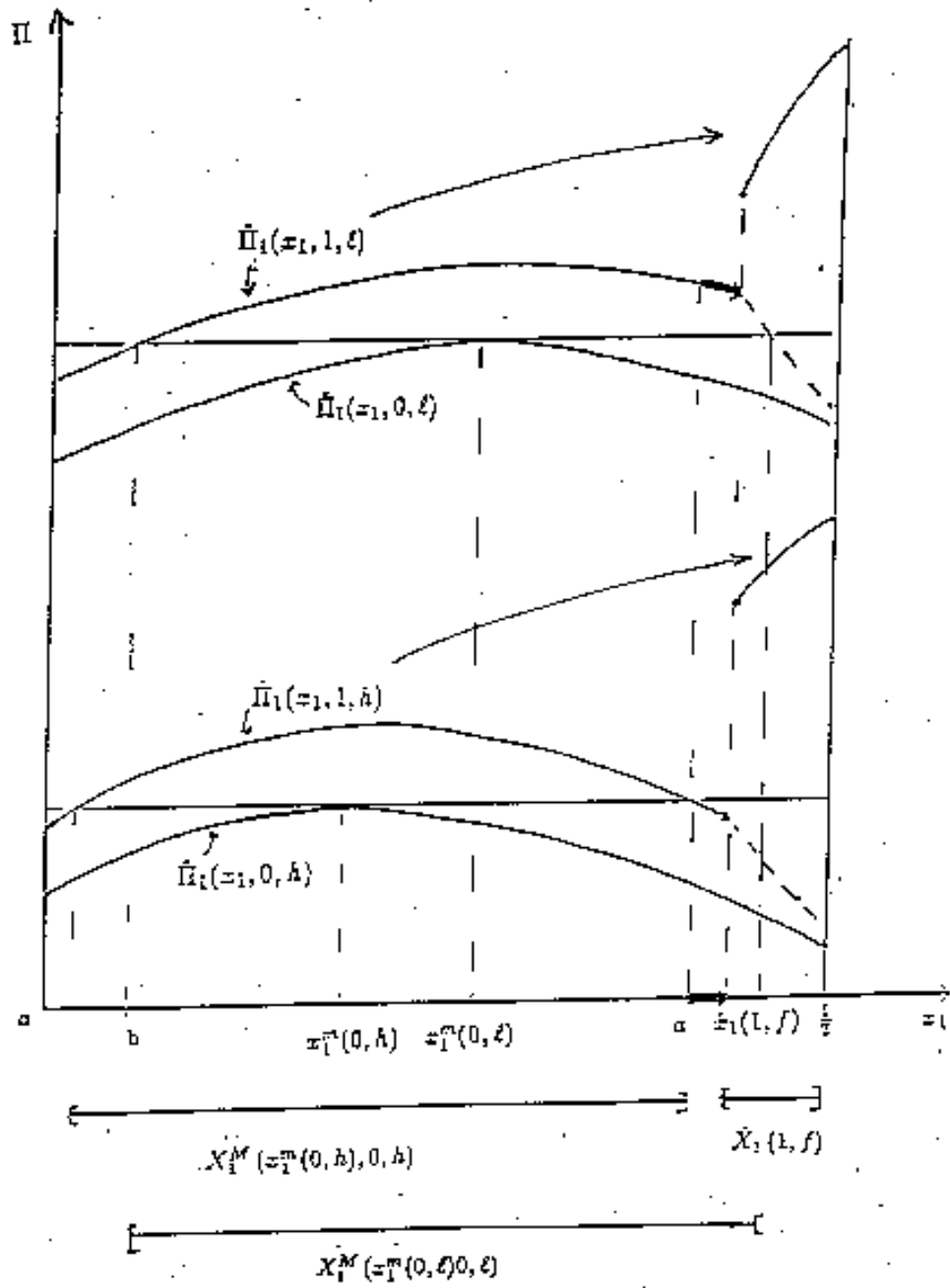
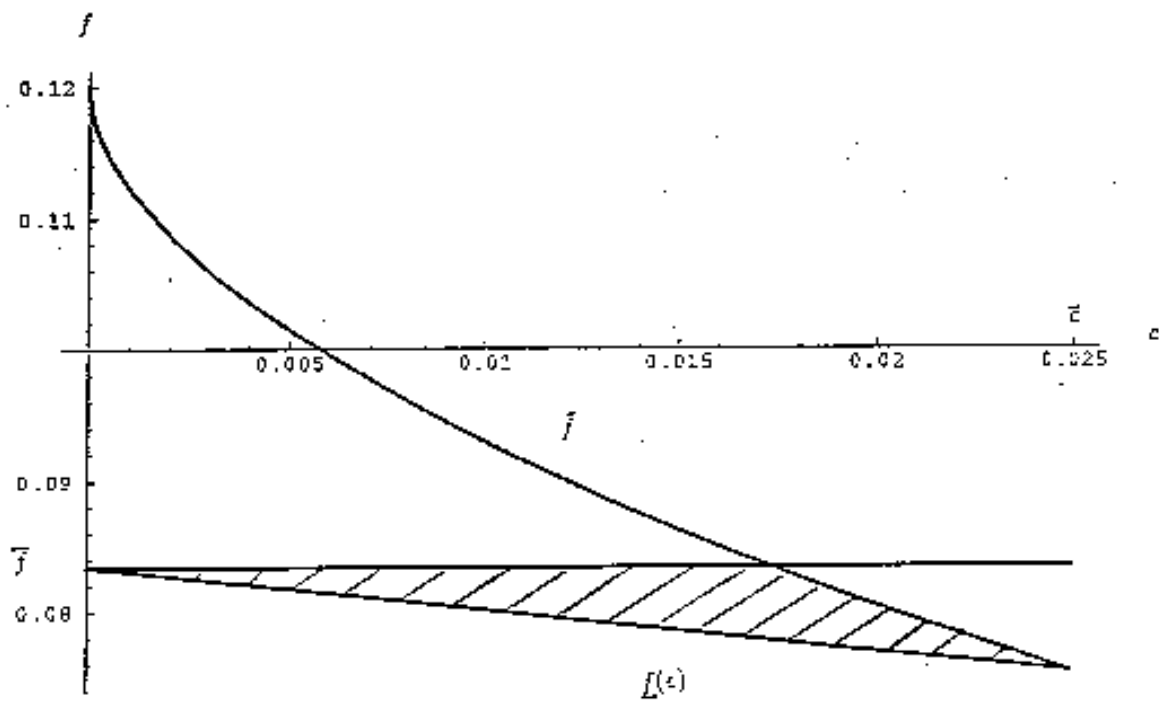FIGURE 2

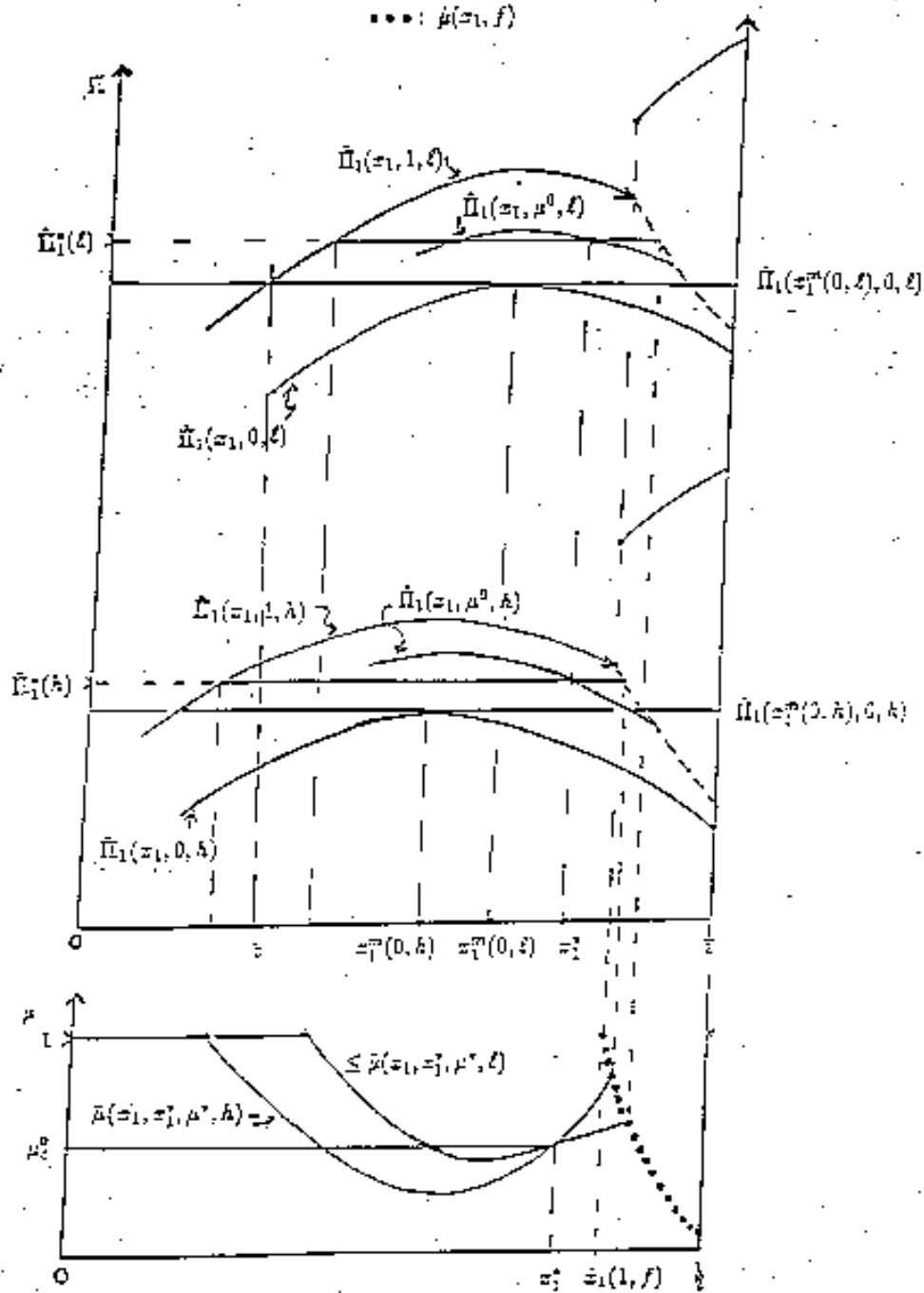VALUES (f, c) FOR WHICH SEPARATING EQUILIBRIA EXISTS

FIGURE 3

POOLING EQUILIBRIUM LOCATIONS : connected set $[b, \frac{1}{2}]$

$\bullet\bullet\bullet : \hat{\mu}(x_1, f)$

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