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Entry Deterrence Through Fixed Cost-Reducing R&D

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Abstract

The paper explores the role of R&D investments reducing fixed production costs in entry deterrence. An incumbent monopolist performs R&D to reduce its fixed production costs. There is a potential entrant, which can also perform R&D for the same purpose. There are bidirectional technological spillovers between the incumbent and the potential entrant. It is shown that deterrence, which takes the form of underinvestment in R&D by the incumbent, is more likely when the spillover from the incumbent to the potential entrant is high, when the spillover from the potential entrant to the incumbent is low, and when the fixed cost is intermediate. The comparative statics of the model depend heavily on which of two cases obtains: the first case is when separation between deterrence and accommodation is dictated by the relative profitability of these strategies; the second case is when separation between these two strategies is dictated by the positivity of R&D investments. The role of two policy tools, R&D subsidies and intellectual property protection, is examined. R&D subsidies, while they generally facilitate entry, move R&D investments in socially undesirable directions, except when accommodation is the equilibrium with and without the subsidy. As for intellectual property rights, they have no effect on R&D investments (except under deterrence) and tend to reduce entry.

Keywords: Entry deterrence, Fixed costs, R&D, R&D spillovers
JEL classification: D42, L12, O33

Résumé

Le papier examine le rôle des investissements en R&D réduisant les coûts fixes de production dans la dissuasion de l'entrée. Un monopoleur établi investit dans la R&D afin de réduire ses coûts fixes de production. Un entrant potentiel peut investir en R&D pour la même fin. Il existe des externalités technologiques bidirectionnelles entre la firme établie et l'entrant potentiel. Il est démontré que la dissuasion de l'entrée, qui prend la forme d'un sous-investissement en R&D par la firme établie, est plus probable lorsque l'externalité de la firme établie vers l'entrant potentiel est élevée, lorsque l'externalité de l'entrant potentiel vers la firme établie est faible, et lorsque le coût fixe est intermédiaire. La statique comparative du modèle dépend duquel des deux cas suivants est observé: le premier cas est lorsque la séparation entre la dissuasion et l'accommodation est déterminée par la profitabilité relative de ces stratégies; le deuxième cas est lorsque la séparation entre ces deux stratégies est déterminée par la contrainte de non négativité des investissements en R&D. Le rôle de deux instruments de politique économique, les subventions à la R&D et la protection de la propriété intellectuelle, est examiné à la lumière des résultats. Les subventions, tout en facilitant l'entrée en général, affectent les investissements en R&D dans des directions socialement indésirables, sauf lorsque l'accommodation est l'équilibre avec et sans les subventions. Quant à la protection de la propriété intellectuelle, elle n'a pas d'effet sur les investissements en R&D (sauf en cas de dissuasion) et tend à réduire l'entrée.

Mots clés: Dissuasion de l'entrée, Coûts fixes, R&D, Externalités technologiques
Classification JEL: D42, L12, O33

1. Introduction

R&D is used by firms to introduce new products and reduce different types of costs, such as fixed and variable costs. Yet, the cost reducing R&D literature has focussed on R&D aiming at reducing variable production costs, neglecting the impact of R&D on fixed costs. But technological improvements can be used to reduce fixed costs as well. For example, a firm may find a way of running its operations using a personal computer rather a mini or a super computer. Or it may invent a device which allows it to reduce the space required for production (smaller machines), which would reduce the fixed capital costs of production. These advances may be copied -in part or completely- by other firms, which would allow them to reduce their fixed production costs as well. Those other firms may be actual competitors, but may also be potential entrants to the industry. Hence R&D investments affecting fixed production costs can affect the profitability of entry. The entry deterrence literature,[1] while it has analysed in length the effect of fixed costs on entry and deterrence, has typically treated those costs as exogenous. Yet, the possibility of performing R&D to reduce fixed production costs makes those costs endogenous. This creates a problem of entry deterrence in the presence of endogenous fixed costs.[2]

This paper explores the role of R&D investments reducing fixed production costs in entry deterrence in the presence of technological spillovers. An incumbent monopolist performs R&D to reduce its fixed production costs. There is a potential entrant, which can also perform R&D for the same purpose. There are bidirectional technological spillovers between the incumbent and the potential entrant. A classical blocking/deterrence/accommodation continuum arises, with the equilibrium outcome depending on fixed costs. The only way of deterring entry in this model is for the incumbent to underinvest in R&D. It will be shown that deterrence is more likely to constitute an equilibrium when the spillover from the incumbent to the potential entrant is high, when the spillover from the potential entrant to the incumbent is low, and, as expected, when the fixed cost is intermediate.

In contrast to the standard entry deterrence model, here two cases have to be considered. The first case is when the separation between deterrence and accommodation is dictated by the relative profitability of these strategies. The second case is when the separation between these two strategies is dictated by the positivity of R&D investments. In that second case, the firm switches from deterrence to accommodation (as the initial fixed production cost declines, say) not because it prefers to do so, but because deterrence is no longer feasible, as it would require a negative R&D

[1] Much of it building on the models of Spence (1977) and Dixit (1980).

[2] This concept should not be confused with the literature on endogenous fixed costs (Sutton, 1991), where fixed costs are typically R&D or advertising costs.

investment. The comparative statics of the model (in particular, the effect of parameters on deterrence and accommodation) depend heavily on the environment in which the firm operates (case 1 or case 2). For instance, in case 1 an increase in the cost of R&D increases deterrence, while in case two it reduces deterrence.

The role of two important policy tools, R&D subsidies and intellectual property protection, is examined. R&D subsidies, while they generally facilitate entry, move R&D investments in socially undesirable directions (inducing overinvestment in R&D under blocking, or accentuating underinvestment under deterrence), except when accommodation is the equilibrium with and without the subsidy. As for intellectual property rights, they are mostly counterproductive: stronger patent protection/intellectual property rights (lower spillovers) have no effect on R&D investments (except under deterrence) and tend to reduce entry.

The paper is related to the large literature on cost-reducing R&D with spillovers (starting with d'Aspremont and Jacquemin, 1988). However, much of this literature has dealt with cost reductions aimed at variable production costs, rather than fixed costs. Moreover, the market structure in this literature is typically given, ignoring the effect of R&D on entry deterrence.

The paper is also related to the very large literature on entry deterrence (Arvan, 1986, for example). In most of this literature, the fixed production cost is exogenous, whereas it is endogenous in the present work. Peretto (1999) constructs a model with R&D investments and free entry, and focuses on the interaction between market structure and growth. However, in his model firms take entry as given and entrants take R&D as given, hence there is no strategic behaviour, and R&D investments are not used to deter or facilitate entry. Moreover, R&D investments are not aimed at reducing fixed production costs.

Of particular relevance to the current work is the segment of the literature which has allowed firms some degree of control over their fixed costs. In a Cournot setting, Neuman et al. (2001) study the tradeoff between fixed and marginal costs. However, this tradeoff is imposed exogenously, and is not the result of R&D investments. They analyse the impact of vertical and horizontal growth in demand on concentration. In the same spirit, Hegji (2001) analyses the tradeoff between fixed and marginal costs, where lower marginal costs require higher fixed costs. While he analyses the optimal investment in fixed costs under blocked and free entry, he does not consider entry deterrence by incumbents. Moreover, he does not allow for technological externalities. In his model firms basically choose a point on the technological frontier, while in the current paper this technological frontier can shift through R&D.

Olczak (2005) studies entry deterrence in a context where one or two firms can raise the fixed costs industry-wide (through regulation or law suits, for example). He shows that raising the fixed cost is an equilibrium strategy when one of the firms is a first-mover in the product market (or believes it is), or when only one of the firms can raise the common fixed cost. However, the amount by which the fixed cost increases is exogenous, and raising the fixed cost is done without incurring any other cost.

Mantena and Sundararajan (2005) model the endogenous choice of product scope by firms facing a bilateral threat of entry in a symmetric oligopoly. The effect on the entrant's fixed cost comes from product scope, where a larger product scope results in higher fixed costs. They derive an equilibrium where a larger product scope is chosen and entry is deterred, as well as an equilibrium where a more limited product scope is implemented and entry is accommodated.[3] While Mantena and Sundararajan focus on product scope as an instrument of raising fixed costs and deterring entry, the model used here is applicable to any technological strategy which aims at keeping fixed costs high, and allows for incorporating the effects of technological spillovers between incumbents and potential entrants. Moreover, in their model the positive effect of product scope on fixed costs is imposed exogenously, making the model less applicable to contexts where this relationship is not so obvious, or to other forms of behaviours aiming at raising fixed costs. Ashiya (2002) analyses entry deterrence when the incumbent and the potential entrant choose the quality of their product, and where the fixed cost depends on the quality chosen. He shows that in equilibrium each firm chooses to produce at most one quality, and quality choice depends on the fixed cost, and can affect the entry decision.

Yet, in most of this work, the interaction between R&D, fixed costs and entry has been overlooked. The role of R&D as an important -potentially fixed- cost which can act as a barrier to entry has been extensively studied, although the focus has not always been on entry. However, the role of R&D in reducing the general fixed costs of the firm has not been explored. Moreover, in the literature, even when the incumbent had some latitude as to the choice of its fixed cost[4] (such as in Arvan, 1986, or Hegji, 2001), the effect on the entry decision is through the impact on the incumbent's variable production costs, rather than through the incumbent's or the entrant's fixed cost of production.

The next section presents the model and analyses the strategic behaviour of the incumbent. Section 3 presents the comparative statics of the model. The role of spillovers is explicitly analysed

[3] The notion that a higher product scope deters entry is also explored in the literature on technological flexibility; see Jacques (2003) for a survey.

[4] Through capacity choice, for example.

in section 4. The last section concludes.

2. The model

A monopolist incumbent produces a good using a technology which involves both variable and fixed costs of production. If the firm remains a monopolist, the difference between revenues and variable costs yields monopoly profits π^m. In addition, the firm incurs the fixed cost F. The firm can invest in R&D to reduce this fixed cost.[5] If the firm spends $\gamma x_i^2/2$, it obtains a cost reduction of x_i. The subscript i refers to the incumbent, γ is a cost parameter, and the convex R&D cost function reflects decreasing returns to scale in R&D.

There is a potential entrant that could enter the market before product market competition takes place. If entry occurs, each firm obtains a difference between revenues and variable costs equal to π^d, with $\pi^m > \pi^d > 0$. If it enters, the entrant must incur a sunk entry cost of S. And to produce, it must incur the fixed production cost, F. However, the entrant can also invest $\gamma x_e^2/2$ in R&D to reduce this fixed cost by x_e. S is assumed to be small enough so as not to make entry unprofitable: $\pi^d > S$.

R&D is assumed to be complementary, hence firms follow different means to reduce their fixed costs. This implies that firms can learn from each other's R&D. R&D is subject to imperfect appropriability: the R&D investment of each firm produces R&D spillovers which benefit the other firm. Let $\beta_i \in (0,1]$ represent the outgoing spillover from the incumbent to the potential entrant,[6] and let $\beta_e \in [0,1]$ be the spillover from the entrant to the incumbent. All R&D investments are made before product market competition takes place. The market is assumed to be always profitable for at least one firm in the absence of entry and R&D: $\pi^m > F$.[7]

If no entry occurs, the profits of the incumbent are given by

$$\pi^m - (F - x_i) - \frac{\gamma}{2} x_i^2 \qquad \textbf{(1)}$$

If entry occurs, the profits of the incumbent and the entrant are

$$\pi^d - (F - x_i - \beta_e x_e) - \frac{\gamma}{2} x_i^2 \qquad \textbf{(2)}$$

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[5] While part of the fixed cost of a firm may be untouched by R&D, some part of it may be reduced through technological progress.

[6] Note that if $\beta_i = 0$, deterrence is not possible: entry is either blocked or accommodated.

[7] It is assumed that the incumbent cannot use other strategies to affect the entry decision, such as excess capacity, advertising, or committing to charging a low price. The goal from this assumption is to focus on R&D as an instrument of entry deterrence.

$$\pi^d - (F - x_e - \beta_i x_i) - \frac{\gamma}{2} x_e^2 - S \qquad \textbf{(3)}$$

If no entry occurs, the incumbent makes higher operational profits, but does not benefit from the R&D investment of the potential entrant (if entry does not occur, the potential entrant operates in another market, and hence does not provide any benefits to the incumbent). If entry occurs, the incumbent makes lower operational profits, but benefits through spillovers from the R&D investment of the potential entrant. The relative profits of the incumbent between the two scenarios will also be affected by the fact that the threat of entry will affect its choice of R&D investment. By investing in R&D, the incumbent reduces its fixed cost, but, by reducing the fixed costs of the potential entrant, may facilitate its entry. Hence, the incumbent may want to use its R&D to affect the entry decision. This entry deterrence comes at the cost of a suboptimal R&D investment, however. The incumbent will follow this strategy if the gains from deterring entry dominate the losses from deviating from the optimal R&D investment (and if entry deterrence is feasible, which, as we will see, is not always the case).

In the absence of a threat of entry, or when entry is inevitable, the profit-maximizing investment in R&D of the incumbent is given by

$$x_i = \frac{1}{\gamma} \qquad \textbf{(4)}$$

In these cases the incumbent simply equates the marginal gain from investment with the marginal cost of R&D. And if entry occurs, the entrant chooses the same R&D investment:

$$x_e = \frac{1}{\gamma} \qquad \textbf{(5)}$$

These are the privately optimal investments. When there is no entry, (4) also gives the socially optimal investment, since all the benefits from R&D are appropriated by the monopolist. Contrarily to R&D affecting variable costs, which affects consumer surplus and the variable costs of competitors (through spillovers), there is no systematic underinvestment in R&D affecting fixed costs. If entry is not an issue, a monopolist invests the socially optimal amount on R&D, because it appropriates all the benefits of R&D. When, however, entry has occurred, both firms are in fact underinvesting in R&D, since the socially optimal investments are given by

$$x_i = \frac{1+\beta_i}{\gamma}, \quad x_e = \frac{1+\beta_e}{\gamma} \qquad \textbf{(6)}$$

The extent of underinvestment in R&D increases with spillovers. In the absence of spillovers investments are socially optimal, but any firm producing spillovers is underinvesting in R&D. This is even though R&D here, for a given market structure, does not affect the competitive positions of firms. But underinvestment is still present because of the imperfect appropriability of R&D. In the presence of a threat of entry, underinvestment may occur when investing the optimal amount of R&D is not profitable because it facilitates entry.

To avoid an uninteresting corner solution, F is assumed to be high enough so that even if both firms invested the privately optimal amount in R&D, and spillovers were perfect, fixed costs would not become negative, that is, $F>2/\gamma$.

The game has four stages. In the first stage, the incumbent invests in R&D; this investment is publicly observable. In the second stage, the entrant decides whether to enter or not, and implements its decision. In the third stage, the entrant, if it has entered, invests in R&D. In the last stage, production and sales take place.

2.1 Strategic behaviour

We now consider the incentives for entry and entry deterrence. Entry is blocked if it is not profitable to the entrant, without the incumbent engaging in any strategic behaviour. In this case, the incumbent chooses (4) as R&D investment. Substituting this level of investment into (2) yields the profits of the incumbent when entry is blocked:

$$\pi_i^B = \pi^m - F + \frac{1}{2\gamma} \qquad \textbf{(7)}$$

Firms will be in this situation if, given this choice of R&D by the incumbent, the entrant would find it unprofitable to enter, even when it reduces its fixed cost by investing the privately optimal amount in R&D, given by (5). Substituting (4) and (5) into (3) yields the condition for blocking:

$$\pi_e = \pi^d - F + \frac{1+2\beta_i}{2\gamma} - S \le 0 \qquad \textbf{(8)}$$

Solving for F yields the minimal value of F allowing blocking:

$$F_{DB} \equiv \frac{1+2\beta_i}{2\gamma} + \pi^d - S \qquad \textbf{(9)}$$

where the subscript DB indicates that this critical value of F will in fact separate deterrence from blocking.

If $F<F_{DB}$, entry is not blocked, and the entrant would find it profitable to enter, given that the incumbent is investing x_i=$1/\gamma$. The only way the incumbent can affect the entry decision is through

its R&D investment. Given that the incumbent's R&D benefits the entrant through β_i, the strategy to follow is obviously to underinvest in R&D relative to the case where entry was blocked. Given that underinvestment in R&D is costly to the incumbent, it will choose the highest R&D investment which does not exceed $1/\gamma$ and which makes entry unprofitable.

Let x_i^D represent the R&D investment of the incumbent under entry deterrence. The profits of the entrant if it enters (and invests the privately optimal amount of R&D) would then be

$$\pi_e = \pi^d - F + \frac{1}{2\gamma} + \beta_i x_i^D - S \qquad \textbf{(10)}$$

Solving for x_i yields the entry deterring level of R&D investment by the incumbent:

$$x_i^D = \frac{F + S - \pi^d}{\beta_i} - \frac{1}{2\beta_i \gamma} \qquad \textbf{(11)}$$

When the incumbent chooses this level of R&D, entry does not occur, and it acts as a monopolist. However, this monopoly position is achieved at the cost of a suboptimal R&D investment, and hence a fixed production cost which is not "optimal". x_i^D decreases with β_i, because a higher β_i means that the potential entrant benefits more from the incumbent's R&D, so to make entry unprofitable the incumbent has to depress its R&D further. There is a fundamental asymmetry between the incumbent and the potential entrant, in that the incumbent can underinvest to deter entry, but the potential entrant cannot manipulate its R&D investment to avoid being deterred.

When $x_i^D > 0$, $\pi^d < F+S$: the potential entrant needs R&D to make entry profitable. In fact, for entry deterrence to work, π^d has to be sufficiently lower than $F+S$ (to compensate for the second term of (11), which is negative), so that x_e by itself is not sufficient, the entrant also needs to benefit from the incumbent's R&D through β_i.

Note also that $\partial x_i^D/\partial \gamma > 0$. This is so for strategic reasons: as the cost of R&D increases, $x_e = 1/\gamma$ decreases (if the entrant were to enter), making entry less profitable for the entrant. Hence deterrence is easier, and can be achieved with a smaller distortion in R&D by the incumbent, i.e., a larger x_i^D.

Substituting x_i^D into (1) yields deterrence profits:[8]

$$\pi_i^D = \pi^m - F + [2\gamma(F + S - \pi^d) - 1]\frac{4\beta_i - [2\gamma(F + S - \pi^d) - 1]}{8\beta_i^2 \gamma} \qquad \textbf{(12)}$$

Deterrence profits decrease with β_i:

8 π^d represents duopoly profits of any firm, while π_i^D represents the deterrence profits of the incumbent.

$$\frac{\partial \pi_i^D}{\partial \beta_i} = \frac{(2\gamma(F+S-\pi^d)-1)^2}{4\beta_i^3\gamma} - \frac{2\gamma(F+S-\pi^d)-1)}{2\beta_i^2\gamma} \qquad \textbf{(13)}$$

This derivative is negative iff

$$\frac{2\gamma(F+S-\pi^d)-1}{2\beta_i\gamma} < \frac{1}{\gamma} \qquad \textbf{(14)}$$

which is true because the l.h.s. is nothing but x_i^D and the r.h.s. is R&D output when entry is blocked (or accommodated), and x_i^D<$1/\gamma$. Deterrence profits decrease with β_i because a higher β_i increases the distortion in R&D investment necessary to deter entry.

Moreover, deterrence profits first increase then decrease with the cost of R&D. This is most easily seen graphically (figure 1). They first increase with γ because a higher γ makes deterrence easier by inducing a reduction in x_e, which allows the incumbent to raise x_i^D, deterring entry with a lower distortion in R&D investment. However, as γ increases further, the negative effect on π_i^D of more costly R&D, along with the increase in x_i^D, come to dominate, and π_i^D declines with γ.

If the incumbent accommodates entry, there is no reason to distort R&D investments, hence the R&D output of each firm will be $1/\gamma$. Accommodation profits are given by

$$\pi_i^A = \pi^d - F + \frac{1+2\beta_e}{2\gamma} \qquad \textbf{(15)}$$

Note that $\partial\pi_i^A/\partial\beta_e>0$, because the incumbent benefits more from the R&D investment of the entrant.

The incumbent will prefer deterrence to accommodation when $\pi_i^D>\pi_i^A$. From (12) and (15), this is true when

$$F > F_{AD} \equiv \pi^d - S + \frac{0.5 + \beta_i(1-\gamma\sqrt{2[\gamma(\pi^m-\pi^d)-\beta_e]})}{\gamma} \qquad \textbf{(16)}$$

Because $\partial x_i^D/F>0$, a very low value of F means a significant distortion in R&D investment, making deterrence too costly.

However, for deterrence to arise in the interval $F \in [F_{AD}, F_{DB}]$, deterrence must be feasible. That is, for the comparison between π_i^A and π_i^D to be relevant, it must be that $x_i^D>0$ in the neighbourhood of F_{AD}. Setting $x_i^D>0$ and solving for F from (11) yields

$$F > F_x \equiv \pi^d - S + \frac{1}{2\gamma} \qquad \textbf{(17)}$$

$x_i^D>0$ iff $F>F_x$. Hence, it does not make sense to talk about deterrence in a region where $F<F_x$,

since deterrence would then require a negative R&D investment. In such a region, even if $\pi_i^D > \pi_i^A$ (so that $F > F_{AD}$), deterrence is not feasible, and the only possible choice is accommodation.

The relative levels of F_{AD} and F_x determine which of the two is relevant for the separation between deterrence and accommodation. It is always $max\{F_{AD}, F_x\}$ which is relevant for this choice. On one hand, when $F_{AD} > F_x$, the firm will switch from deterrence to accommodation at a point where $\pi_i^A > \pi_i^D$ and $x_i^D > 0$; that is, deterrence is still feasible, but the firm prefers to switch to accommodation, because deterrence has become too costly. When, on the other hand, $F_{AD} < F_x$, the firm will switch from deterrence to accommodation at a point where $\pi_i^D > \pi_i^A$ but $x_i^D = 0$: it is impossible to reduce R&D further to deter entry, hence accommodation is the equilibrium.

Moreover, there are parameter values such that $F_{AD} \gtrless F_x$. To see that,

$$F_{AD} - F_x = \beta_i \frac{1 - \sqrt{2[\gamma(\pi^m - \pi^d) - \beta_e]}}{\gamma} \qquad \textbf{(18)}$$

There exist parameter values that make this difference positive or negative. F_{AD} is more likely to be larger when π^d and β_e are large, and when π^m and γ are small. Large values of π^d and β_e increase the relative benefits of accommodation, making π_i^D and π_i^A cross at a larger value of F. A small value of π^m has the opposite effect of π^d. Above it was noted that $\partial x_i^D / \partial \gamma > 0$, hence a small value of γ makes x_i^D approach zero for higher values of F, i.e., γ reduces F_x. But γ also reduces F_{AD}, and it tends to reduce it faster than it reduces F_x, especially for higher values of γ.

Figure 2 illustrates the two possible cases. In figure 2a, $F_{AD} > F_x$, implying that F_x is irrelevant for the choice between deterrence and accommodation, because as F declines, the firm will prefer to accommodate even though deterrence is still feasible. In figure 2b, however, F_{AD} is irrelevant for the choice between deterrence and accommodation, meaning that the comparison between π_i^A and π_i^D is irrelevant. In this case, as F declines, the firm will choose to accommodate when deterrence is no longer feasible, i.e., when $x_i^D < 0$. In fact, in the range $F \in (F_{AD}, F_x)$ in figure 2b, $\pi_i^D > \pi_i^A$, but the firm chooses accommodation, because $x_i^D < 0$.

While both scenarios entail that {accommodation, deterrence, blocking} occurs for {low, intermediate, high} values of F, they imply sometimes radically different comparative statics, as is shown in the next section.

Figure 3 shows the relationship between the profits of the incumbent and F in the case corresponding to Figure 2a, i.e., when $F_{AD} > F_x$, while figure 4 shows the equivalent in the case of figure 2b. In both cases profits decline with F in the accommodation and blocking phases, but increase with it for most of the deterrence phase, because a higher F makes deterrence easier (given that entry is deterred). The difference between the two figures lies in the discontinuity in profits in figure 4 between the accommodation and deterrence phases. For values of F close to, but lower, than F_x, the firm prefers deterrence, but deterrence is not feasible. As soon as F reaches F_x, deterrence becomes feasible, and profits "jump" to π_i^D. In figure 3, however, at the separation between the accommodation and deterrence phases, the firm is just indifferent between accommodation and deterrence, hence the two curves cross.

Proposition 1 summarizes the strategic behaviour of the incumbent.

Proposition 1.
-When $F>F_{DB}$, entry is blocked and $x_i=1/\gamma$;
-when $\max\{F_{AD},F_x\}\leq F\leq F_{DB}$, the incumbent deters entry by investing $x_i^D<1/\gamma$;
-when $F_{AD}>F\geq F_x$, entry is accommodated because $\pi_i^A>\pi_i^D$. Moreover, $x_i=1/\gamma$;
-when $F_{AD}\leq F<F_x$, entry is accommodated because $x_i^D<0$. Moreover, $x_i=1/\gamma$;
with F_{DB}, F_{AD}, F_x, and x_i^D given by (9), (16), (17) and (11).
Proof. Section 2.1. ■

3. Comparative statics

We can now analyse how changes in the environment will affect the strategic behaviour of the incumbent and hence the equilibrium outcome. Consider first the effect of β_i.

Proposition 2. *An increase in β_i reduces blocking and increases deterrence. In addition:*
- if $F_{AD}<F_x$, it has no effect on accommodation;
- if $F_{AD}>F_x$, it increases accommodation.
Proof. It is obvious from (9) that $\partial F_{DB}/\partial\beta_i>0$, hence β_i always reduces blocking. And from (16) we know that $\partial F_{AD}/\partial\beta_i>0$ when $F_{AD}>F_x$ (in this and all following proofs, only the highest of F_x and F_{AD} is relevant). Note that the term

$$1-\gamma\sqrt{2[\gamma(\pi^m-\pi^d)-\beta_e]} \qquad \textbf{(19)}$$

which multiplies β_i in (16) is positive when $F_{AD}>F_x$ by virtue of (18).
And F_x does not depend on β_i.
Hence, when $F_{AD}<F_x$, F_{DB} shifts to the right, implying that there is less blocking, more deterrence, and no change in accommodation.
When $F_{AD}>F_x$, both F_{DB} and F_{AD} shift to the right. This increases accommodation and reduces

blocking. To determine the net effect on deterrence, we take the difference

$$\frac{\partial(F_{DB}-F_{AD})}{\partial\beta_i}=\frac{\sqrt{2[\gamma(\pi^m-\pi^d)-\beta_e]}}{\gamma}>0 \qquad \textbf{(20)}$$

Hence F_{DB} shifts to the right more than F_{AD}, and deterrence increases. ■

The increase in β_i increases the benefit to the potential entrant from the R&D investment of the incumbent, and reduces the extent of blocking. When $F_{AD}<F_x$, the separation between deterrence and accommodation is determined by the constraint $x_i^D>0$. From (17) we know that F_x does not depend on β_i, because the positivity of x_i^D does not depend on β_i. Hence in this case F_x does not move, and there is no effect on accommodation. However, because F_{DB} has shifted to the right, there is now more deterrence. This increase in deterrence is achieved at the cost of a decrease in x_i^D (from (11) we know that $\partial x_i^D/\partial\beta_i<0$), because a higher β_i means that the potential entrant benefits more from the incumbent's R&D, so to make entry unprofitable the incumbent has to depress its R&D further.

When $F_{AD}>F_x$, the separation between deterrence and accommodation is determined by whether $\pi_i^A \gtrless \pi_i^D$. The increase in β_i makes deterrence more costly, hence the firm chooses to accommodate more often, and F_{AD} shifts to the right. Given that $\partial F_{DB}/\partial\beta_i>\partial F_{AD}/\partial\beta_i$, the inverse function rule implies that

$$-\frac{\frac{\partial\pi_e}{\partial\beta_i}}{\frac{\partial\pi_e}{\partial F}}>-\frac{\frac{\partial(\pi_i^A-\pi_i^D)}{\partial\beta_i}}{\frac{\partial(\pi_i^A-\pi_i^D)}{\partial F}} \qquad \textbf{(21)}$$

Given that, by the envelope theorem, at the optimum the impact of F on all profit levels is the same, this inequality means that F_{DB} shifts more than F_{AD} because the quantitative impact of β_i on the potential entrant's profits is larger than its effect on the difference between accommodation and deterrence profits.

Consider next the consequences of an increase in the potential entrant's spillover.

Proposition 3. *An increase in β_e has no effect on blocking. In addition:*

- if $F_{AD}<F_x$, it has no effect on deterrence or accommodation;

-if $F_{AD}>F_x$, it reduces deterrence and increases accommodation.

Proof. β_e does not affect F_{DB}, and hence has no effect on blocking. Moreover, β_e does not affect F_x, and hence when $F_{AD}<F_x$, it has no effect on deterrence or accommodation either. However, it is clear

from (16) that $\partial F_{AD}/\partial\beta_e>0$, hence when $F_{AD}>F_x$, the increase in β_e shifts F_{AD} to the right, reducing deterrence and increasing accommodation. ■

The increase in β_e has no effect on blocking because it only affects the extent to which the incumbent benefits from x_e. When $F_{AD}<F_x$, F_x is relevant, but β_e does not affect F_x, hence there is no effect either on deterrence or accommodation. In this case the spillover of the potential entrant is totally irrelevant to the entry/deterrence decisions.

When $F_{AD}>F_x$, at F_{AD} the incumbent is indifferent between accommodation and deterrence. The increase in β_e increases the benefit of the incumbent from the potential entrant's technology, hence the incumbent decides to accommodate more often, and F_{AD} shifts to the right.

The following proposition describes the effect of an increase in the cost of R&D.

Proposition 4. *An increase in* γ *increases blocking and reduces accommodation. In addition:*

- *if* $F_{AD}<F_x$, *it reduces deterrence;*
- *if* $F_{AD}>F_x$, *it increases deterrence.*

Proof. It is clear from (9) and (17) that $\partial F_{DB}/\partial\gamma<0$ and $\partial F_x/\partial\gamma<0$. And

$$\frac{\partial F_{AD}}{\partial\gamma}=\frac{\sqrt{2}\beta_i[\gamma(\pi^m-\pi^d)-2\beta_e]-(1+2\beta_i)\sqrt{\gamma(\pi^m-\pi^d)-\beta_e}}{2\gamma^2\sqrt{\gamma(\pi^m-\pi^d)-\beta_e}} \qquad \textbf{(22)}$$

To sign this expression, we need to sign its numerator. Let

$$k\equiv\sqrt{\gamma(\pi^m-\pi^d)-\beta_e} \qquad \textbf{(23)}$$

The numerator of (22) can then be rewritten as

$$\sqrt{2}\beta_i[k^2-\beta_e]-(1+2\beta_i)k \qquad \textbf{(24)}$$

A sufficient condition for (24) to be negative is

$$\sqrt{2}\beta_i k^2-2\beta_i k<0 \qquad \textbf{(25)}$$

which requires $k<\sqrt{2}$. But from (18) we know that when $F_{AD}>F_x$ (this makes F_{AD} relevant), $k<1/\sqrt{2}$, which is sufficient to guarantee the negativity of (25), hence $\partial F_{AD}/\partial\gamma<0$.

These results imply that in all cases there is more blocking and less accommodation. Also, the range of F where deterrence occurs has shifted to the left. To know if this range has increased or decreased, we need to look at the extent of the shift in the critical values of F. Consider first the case where $F_{AD}<F_x$. In this case,

$$\frac{\partial(F_{DB}-F_x)}{\partial\gamma} = -\frac{\beta_i}{\gamma^2} < 0 \qquad \textbf{(26)}$$

hence F_{DB} shifts more than F_x, and there is less deterrence.

When $F_{AD}>F_x$,

$$\frac{\partial(F_{DB}-F_{AD})}{\partial\gamma} = -\beta_i \frac{\gamma(\pi^m-\pi^d)-2\beta_e}{\gamma^2\sqrt{2[\gamma(\pi^m-\pi^d)-\beta_e]}} \qquad \textbf{(27)}$$

This expression is positive iff the numerator is negative, which requires

$$\gamma(\pi^m-\pi^d)-2\beta_e < 0 \qquad \textbf{(28)}$$

We know from (18) that when $F_{AD}>F_x$,

$$\beta_e > \gamma(\pi^m-\pi^d)-\frac{1}{2} \qquad \textbf{(29)}$$

We replace β_e in (28) by the r.h.s. of (29), which preserves the sign of (28). Equation (28) becomes $\gamma(\pi^m-\pi^d)>1$, which is true because the maximum value of β_e is 1, hence we know that $\gamma(\pi^m-\pi^d)\geq 1$. Therefore the numerator of (27) is negative, F_{AD} shifts more than F_{DB}, and there is more deterrence.■

The increase in the cost of R&D reduces the privately optimal R&D investments given by (4) and (5). As the incumbent reduces its R&D, the benefit flowing to the potential entrant from the incumbent's R&D decreases. In addition, the cost of R&D of the potential entrant increases. These two factors combine to block entry more often.

When γ increases, F_x shifts to the left, reflecting the fact that $\partial x_i^D/\partial\gamma>0$. As γ increases, the constraint on the nonnegativity of x_i^D is relaxed, F_x shifts to the left, and there is less accommodation. And even though both F_{DB} and F_x shift to the left, the shift in F_{DB} is more important, implying that the extent of deterrence is reduced, even though it now occurs for lower values of F. The reason why F_{DB} shifts more than F_x can be understood by looking at how they vary with γ. By the envelope theorem

$$\frac{\partial\pi_e(x_e^*)}{\partial\gamma} = \frac{\partial F_{DB}}{\partial\gamma} = \beta_i\frac{\partial x_i^A}{\partial\gamma} - \frac{x_e^2}{2} \qquad \textbf{(30)}$$

where $x_e^*=1/\gamma$. The first term on the r.h.s. of (30) represents the loss to the potential entrant from the decline in R&D by the incumbent.[9] The second term represents the effect of the increase in the cost of R&D on the potential entrant's profit if it were to enter. Whereas

$$\frac{\partial F_x}{\partial \gamma} = -\frac{x_e^2}{2} \qquad \textbf{(31)}$$

The effect of the change in x_i^D on the potential entrant's profit does not affect the condition that $x_i^D>0$, hence the shift in F_{DB} is larger (than the shift in F_x), because it incorporates that effect. This explains why deterrence declines following an increase in γ when F_x is relevant.

When $F_{AD}>F_x$, the tradeoff between π_i^A and π_i^D shifts toward π_i^D when γ increases, because x_e has declined, and the incumbent can afford to deter entry while reducing the distortion in its own R&D, that is, increasing x_i^D. Hence there is less accommodation. Moreover, the shift in F_{AD} is larger than the shift in F_{DB}, the net effect is to increase deterrence, even though it now occurs for lower values of F. By the inverse function rule, $|\partial F_{AD}/\partial\gamma|>|\partial F_{DB}/\partial\gamma|$ means that

$$\left| -\frac{\dfrac{\partial(\pi_i^A-\pi_i^D)}{\partial\gamma}}{\dfrac{\partial(\pi_i^A-\pi_i^D)}{\partial F}} \right| > \left| -\frac{\dfrac{\partial\pi_e}{\partial\gamma}}{\dfrac{\partial\pi_e}{\partial F}} \right| \qquad \textbf{(32)}$$

Given that at the optimum the impact of F on all profit levels is the same, this inequality means that F_{AD} shifts more than F_{DB} because the quantitative impact of γ on the (absolute value of) the difference between accommodation and deterrence profits is larger than its impact on the potential entrant's profits.

Hence, in this case the increase in the cost of R&D has the paradoxical effects of increasing the R&D of the incumbent *and* increasing deterrence. The net effect on the extent of deterrence can be positive or negative, depending on whether $F_{AD}\gtrless F_x$.

The model allows us to predict the effect of an R&D subsidy on deterrence. The subsidy is equivalent to a reduction in γ. Hence, the subsidy (provided it is available to all firms) always reduces blocking and increases accommodation. Moreover, it should reduce the extent of deterrence, unless $F_{AD}<F_x$, in which case the subsidy would increase deterrence. Hence, overall, the subsidy is expected to make entry occur more often.

When the subsidy is offered but does not affect the outcome (blocking, deterrence, or accommodation), its effect on the optimality of R&D is complex. When entry is blocked, the subsidy

[9]Note that under blocking the incumbent chooses $x_i=1/\gamma$, which is the same as x_i^A.

will induce an overinvestment in R&D, given that the incumbent was already spending the optimal amount.[10] With deterrence, the firm is underinvesting in R&D, but $\partial x_i^D/\partial\gamma>0$, hence the subsidy will reduce x_i^D even more, which is counterproductive. When accommodation is the equilibrium with and without the subsidy, the subsidy is socially beneficial, since both firms invest too little in R&D from the social point of view (with strictly positive spillovers). Therefore, while the subsidy may facilitate entry, when it does not change the type of equilibrium, it is counterproductive, except when the equilibrium is accommodation.

Corollary 1. *An R&D subsidy offered to both firms has the opposite effect of γ on entry. Moreover, when it does not change the equilibrium outcome:*
-it induces an overinvestment in R&D under blocking;
-it accentuates the underinvestment in R&D under deterrence; and
-it moves R&D in the socially desirable direction (up) under accommodation.

Proof. The R&D subsidy reduces the cost of R&D to the firm. Under blocking, the incumbent was investing the socially optimal amount before the subsidy, and the subsidy increases R&D. Under deterrence, the incumbent was underinvesting in R&D, and the subsidy induces it to reduce its R&D. Under accommodation, the incumbent and the entrant are spending too little on R&D (provided $\beta_i,\beta_e>0$), and the subsidy induces them to increase their R&D investments. ■

The effects of profits and of the sunk cost, although well known and largely independent of R&D effects, are presented here for completeness. Moreover, when $F_{AD}<F_x$, the presence of R&D changes the effects of these parameters on the equilibrium. Consider first the impact of an increase in monopoly profits.

Proposition 5. *An increase in π^m has no effect on blocking. In addition:*
- if $F_{AD}<F_x$, it has no effect on deterrence or accommodation;
- if $F_{AD}>F_x$, it increases deterrence and reduces accommodation.

Proof. F_{DB} and F_x do not depend on π^m. From (16) it is obvious that $\partial F_{AD}/\partial\pi^m<0$. Hence, when $F_{AD}<F_x$, none of the relevant critical values shifts, and there is no effect on blocking, deterrence or accommodation. When $F_{AD}>F_x$, the shift of F_{AD} to the left while F_{DB} is unchanged means that there is no effect on blocking, while deterrence has increased and accommodation diminished. ■

[10] With blocking and when there are more than one incumbent, however, the subsidy will be socially beneficial as long as there are spillovers, since in this case firms will underinvest in R&D relative to the social optimum.

Blocking is not affected by the change in π^m, because blocking is determined solely by the potential duopoly profits if the potential entrant enters (minus all R&D costs and plus all R&D benefits). When $F_{AD}<F_x$, F_x is relevant. But F_x does not depend on π^m, hence in this case both deterrence and accommodation are unaffected. When $F_{AD}>F_x$, however, the increase in π^m shifts the tradeoff toward deterrence, and reduces accommodation.

Proposition 6 shows the effect of an increase in π^d on the equilibrium.

Proposition 6. *An increase in π^d reduces blocking and increases accommodation. In addition:*

- if $F_{AD}<F_x$, it has no effect on the extent of deterrence (*but deterrence now occurs for higher values of F*)*;*

- if $F_{AD}>F_x$, it reduces deterrence.

Proof. It is obvious from (9), (16) and (17) that $\partial F_{DB}/\partial \pi^d>0$, $\partial F_x/\partial \pi^d>0$, and $\partial F_{AD}/\partial \pi^d>0$. This means that there is less blocking and more accommodation, both when $F_{AD}<F_x$ and when $F_{AD}>F_x$.

To determine the net effect on deterrence, we need to look at the magnitudes of the changes in the critical values of F. Consider first the case $F_{AD}<F_x$. It is obvious from (9) and (17) that

$$\frac{\partial F_{DB}}{\partial \pi^d} = \frac{\partial F_x}{\partial \pi^d} \qquad \textbf{(33)}$$

hence the two critical values shift to the right by equal amounts, implying that in this case the extent of deterrence (given by the difference F_{DB}-F_x) is unchanged, even though now deterrence occurs for higher values of F.

Consider next the case $F_{AD}>F_x$. In this case the difference in the shift of the critical values is given by

$$\frac{\partial (F_{DB}-F_{AD})}{\partial \pi^d} = -\frac{\beta_i}{\sqrt{2[\gamma(\pi^m-\pi^d)-\beta_e]}} < 0 \qquad \textbf{(34)}$$

hence F_{AD} shifts to the right more, implying a reduction in deterrence. ■

The increase in π^d makes entry easier for any level of R&D investments, reducing blocking. Moreover, when F_x is relevant, x_i^D declines with π^d, meaning that the incumbent has to underinvest more to deter entry. The constraint $x_i^D>0$ becomes binding for higher values of F, implying that F_x shifts to the right and there is more accommodation. As F_{DB} and F_x shift by similar amounts, the extent of deterrence is unchanged, although it now occurs for higher values of F.

When $F_{AD}>F_x$, the fact that deterrence has become more costly (it requires more underinvestment; remember that $\partial x_i^D/\partial\pi^d<0$) and that accommodation (duopoly) profits have increased, combine to shift F_{AD} to the right, shifting the tradeoff toward accommodation. And as F_{DB} shifts less than F_{AD}, there is less deterrence. Using the same reasoning as above, $\partial F_{AD}/\partial\pi^d>\partial F_{DB}/\partial\pi^d$ means that

$$-\frac{\dfrac{\partial(\pi_i^A-\pi_i^D)}{\partial\pi^d}}{\dfrac{\partial(\pi_i^A-\pi_i^D)}{\partial F}} > -\frac{\dfrac{\partial\pi_e}{\partial\pi^d}}{\dfrac{\partial\pi_e}{\partial F}} \qquad \textbf{(35)}$$

Finally, consider the effect of an increase in the entrant's sunk cost.

Proposition 7. *An increase in S increases blocking, has no effect on the extent of deterrence* (*but deterrence now occurs for lower values of F*), *and reduces accommodation.*

Proof. It is obvious from (9), (16) and (17) that $\partial F_{DB}/\partial S<0$, $\partial F_{AD}/\partial S<0$ and $\partial F_x/\partial S<0$. This means that there is more blocking and less accommodation. Moreover,

$$\frac{\partial F_{DB}}{\partial S}=\frac{\partial F_{AD}}{\partial S}=\frac{\partial F_x}{\partial S} \qquad \textbf{(36)}$$

implying that in all cases there is no change in the extent of deterrence, although it now occurs for lower values of F. ■

The effect of S is straightforward: it makes blocking more likely, facilitates deterrence, and reduces accommodation. When F_x is relevant, F_x shifts to the left because $\partial x_i^D/\partial S>0$. However, because of the equal shifts in F_{DB}, F_{AD} and F_x, S does not affect the extent of deterrence. Moreover, contrarily to π^m and π^d, there is no interaction between the comparative statics of the sunk cost and R&D investments or spillovers.

4. The effect of spillovers

This section looks more closely at the effect of spillovers on the equilibrium. While the results were expressed above in terms of F, here they are stated in terms of critical values of spillovers.

Proposition 8. *Let* $x_i^D>0$ (*i.e.*, $F>F_x$). *Then, entry is blocked when* $\beta_i<\beta_i^{DB}$. *When* $\beta_i>\beta_i^{DB}$: *entry is deterred for* $\beta_e<\beta_e^{AD}$, *and accommodated for* $\beta_e>\beta_e^{AD}$, *with* β_i^{DB} *and* β_e^{AD} *given by* (37) *and* (38).

Proof. Solving (8) for β_i yields the critical value for blocking:

$$\beta_i^{DB} = \gamma(F + S - \pi^d) - \frac{1}{2} \qquad \textbf{(37)}$$

Equating (12) and (15) and solving for β_e *yields*

$$\beta_e^{AD} = \frac{8\beta_i\gamma(F + S - \pi^d) - 4\beta_i + \beta_i^2(8\gamma(\pi^m - \pi^d) - 4) - (1 - 2\gamma(F + S - \pi^d))^2}{8\beta_i^2} \qquad \textbf{(38)} \blacksquare$$

The incumbent prefers deterrence for $\beta_e<\beta_e^{AD}$ and accommodation for $\beta_e>\beta_e^{AD}$ (in both cases, conditional on $\beta_i>\beta_i^{DB}$). Consistent with the comparative statics derived above, it is easy to verify that $\partial\beta_e^{AD}/\partial\beta_i<0$, reflecting that a higher β_i tilts the tradeoff between deterrence and accommodation in favour of the latter.

By fixing other model parameters and letting β_i and β_e vary, we can study the results in the spillover space. Figure 5 plots the equilibrium outcomes for the case $F>F_x$. F_x does not vary with spillovers. Blocking constitutes the equilibrium when β_i is sufficiently low. When β_i is moderate/high and β_e is sufficiently low, deterrence obtains, while accommodation is the equilibrium when β_i is moderate/high and β_e is sufficiently high. These results are consistent with the comparative statics derived in section 4, but here the impact of spillovers on the equilibrium is more explicitly shown: a higher β_i reduces blocking while facilitating both deterrence and accommodation, while a higher β_e increases accommodation and reduces deterrence, with no effect on blocking. Note that in the lower region of this figure (below the imaginary line β_e=0.25), $F_{AD}<F_x$, while above that line $F_{AD}>F_x$. But because $F>F_x$, this inequality does not affect the equilibrium, that is, there is no region on this figure where the firm would like to deter entry but cannot.

Figure 6 illustrates such a case using the same numerical parametrization as figure 5, except for F, so that with $F<F_x$, the equilibrium is *Accommodation* everywhere. However, in the lower right part of the graph (for moderate/high β_i and low β_e), the incumbent chooses *Accommodation*, even though it would prefer deterrence ($F>F_{AD}$), because of the constraint $x_i^D>0$: deterrence would require a negative R&D investment. Moreover, entry is never blocked on this figure because of the relatively low value of F.

These results allow us to predict the impact of intellectual property protection on market structure and R&D. The model predicts that strengthening the protection of the incumbent's technology (a reduction in β_i) increases the chances that entry will be blocked and/or deterred (see figure 5). More precisely, the chances of deterrence increase when β_i is much larger than β_i^{DB}. Given that this would be done at the expense of accommodation, such a policy would be welfare-reducing. When β_i is just above β_i^{DB}, reducing β_i would induce a shift from deterrence to blocking. This is welfare-increasing, because blocking does not entail a distortion in x_i. Moreover, it has the effect of increasing x_i^D, but only in the deterrence regime. In parallel, strengthening the protection of the entrant's technology (a reduction in β_e) increases the chances that entry will be deterred, and it has no effect on R&D investments. The benefits of increasing the protection of R&D aimed at reducing fixed costs are not obvious (even in the absence of strategic behaviour), given that firms don't suffer strong disincentives from the reduction in the fixed costs of their competitors.[11] In this context, intellectual property protection has little effect on R&D, and mostly negative effects on entry.

5. Conclusions

This paper has shown how underinvestment in R&D aiming at reducing fixed production costs can be used to deter entry. It was shown that deterrence is more likely when the spillover from the incumbent to the potential entrant is high, when the spillover from the potential entrant to the incumbent is low, and when the fixed cost is intermediate.

Underinvesting in R&D to deter entry can be seen as a strategy raising rivals' costs, although it also raises the costs of the incumbent.[12] It can also be seen as a *lean and hungry look* strategy, where the firm underinvests to be strong. Paradoxically, the dominant monopoly position is maintained through inferior innovative performance.[13] Firms may slow technological progress to prolong their monopoly (or high concentration) position. Underinvestment in this type of R&D can be used by public utilities to artificially maintain natural monopoly positions. It is almost impossible for antitrust authorities to detect this type of underinvestment in R&D, in spite of its anticompetitive effects.

The literature on potential competition (for example, Nti, 2000) has pointed out that more potential competition may lead to less actual competition. Here, potential competition can lead to less innovation.

The paper is remotely related to the literature on endogenous sunk costs (Sutton, 1991) which

[11] Unless prices are closely relate to average costs.

[12] The literature has considered activities raising rivals' costs (for example, Salop and Scheffman, 1983) through activities such as raising input prices, regulation, law suits, or R&D expenditures. However, underinvestment in R&D has not been studied as a strategy for raising rivals' costs.

[13] While fixed costs can be affected directly through R&D, many technological choices made by the firm can also affect them. For instance, Caves and Porter (1977) and Mantena and Sundararajan (2005) note that increasing the scope of a product can increase fixed costs, making entry more difficult for any firm wanting to produce a product with similar characteristics. Mantena and Sundararajan cite the example of Microsoft, which has increased the scope of its Windows operating system with that purpose -among other purposes- in mind. Increasing the product scope artificially to boost fixed costs can be seen as an inefficient technological choice aimed at deterring entry, in the same spirit as underinvesting in R&D aimed at reducing fixed costs. In both cases, the best technology available -or that could be made available- is not used or developed.

suggests that concentration may be higher in larger markets through higher levels of R&D (and advertising). Here fixed costs are "endogenous", but obviously in a different sense. In the present framework, endogenous fixed costs may increase as well as decrease concentration (underinvestment in R&D makes deterrence possible, increasing concentration, but spillovers may facilitate entry, decreasing concentration). In contrast to the endogenous sunk costs literature, here the barriers to entry do not come from the high R&D investments of incumbents, but rather from too little R&D investment.

Several papers have looked at the relationship between concentration and R&D (Dasgupta and Stiglitz, 1980, Vives, 2004). The results are inconclusive and model-specific. The results obtained here suggest a complex relationship between concentration and innovation, since higher levels of innovation may be associated with more (under blocking) or less (under accommodation) concentration, while lower levels of innovation may be associated with higher levels of concentration (when entry is deterred).

The paper has shown that spillovers can affect the type of equilibrium that obtains, and through it market structure and R&D investments. Patents and intellectual property protection can have unintended consequences on R&D and market structure (beyond the direct effect of increasing the incentives for innovation) in the presence of strategic effects. With strategic behaviour present, most of the effects of intellectual property protection are on market structure, rather than on R&D investments per se, and those effects tend to be negative (less entry). Combined with the mixed results regarding R&D subsidies derived above (see corollary 1), these results suggest that innovation policy instruments designed for R&D related to variable cost reduction and product innovation have a mixed performance when applied to R&D aimed at reducing fixed production costs in the presence of potential entry and strategic behaviour.

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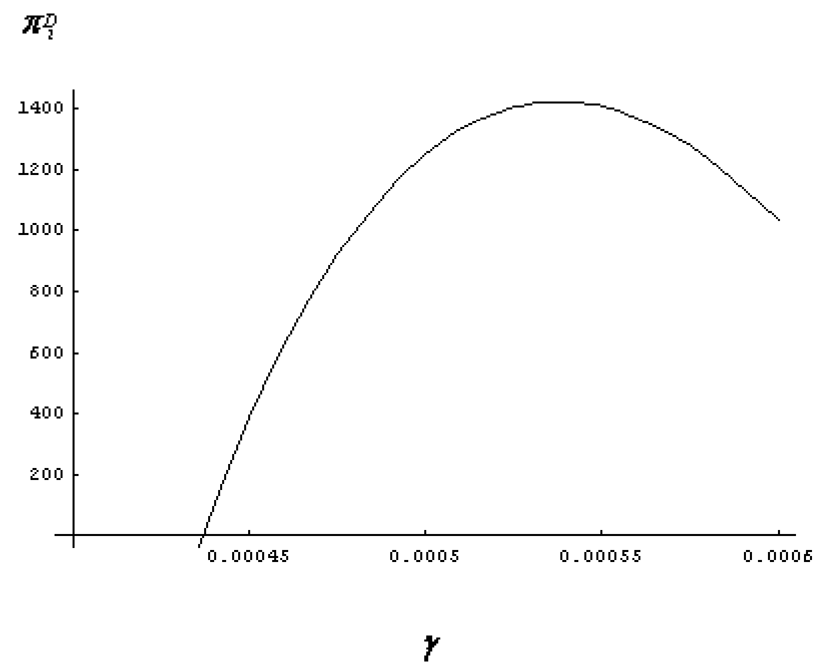
Table 1. Summary of results

	$F_{AD}<F_x$			$F_{AD}>F_x$		
	Accommo-dation	Deterrence	Blocking	Accommo-dation	Deterrence	Blocking
β_i	0	+	-	+	+	-
β_e	+	0	0	+	-	0
γ	-	-	+	-	+	+
π^m	0	0	0	-	+	0
π^d	+	0*	-	+	-	-
S	-	0*	+	-	0*	+

* In these cases the range of fixed costs over which deterrence occurs shifts, but the length of this range remains unchanged.

Figure 1. Incumbent's deterrence profits as a function of the cost of R&D



F=14500, π^d=13500, π^m=15000, S=100, β_i=0.1, β_e=0.5

Figure 2a. $F_{AD} > F_x$

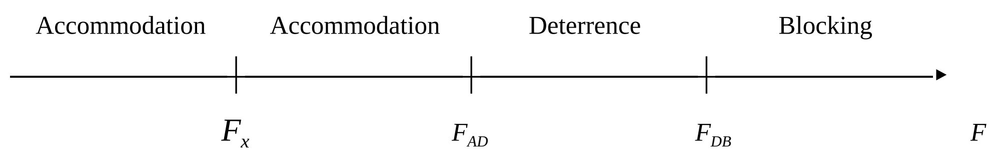


Figure 2b. $F_{AD} < F_x$

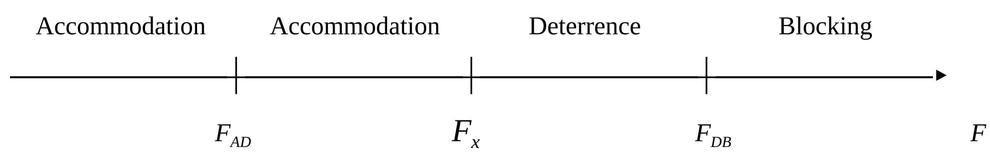
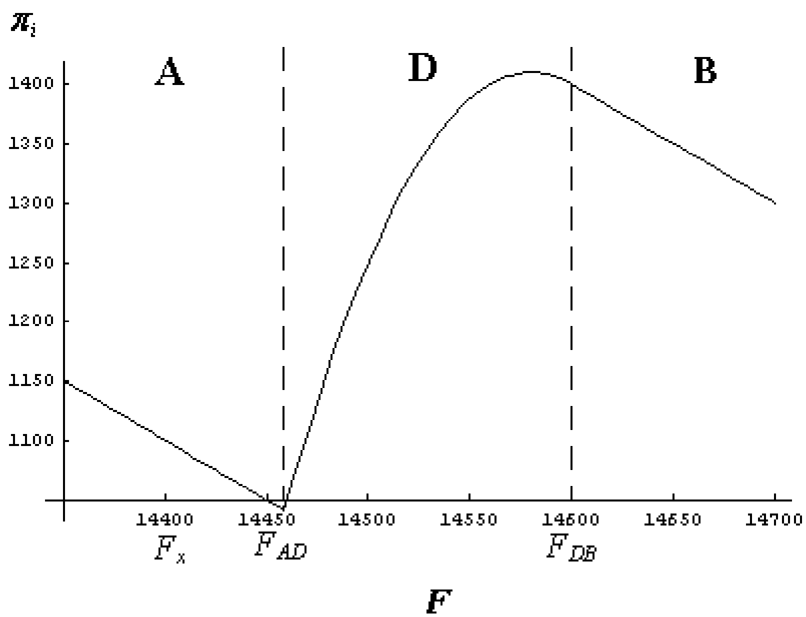
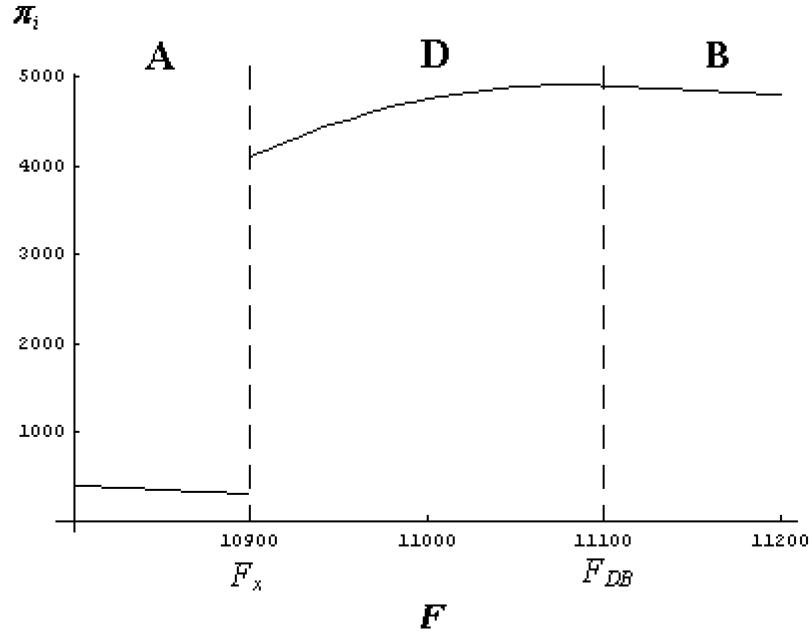


Figure 3. Equilibrium profits: $F_{AD}>F_x$



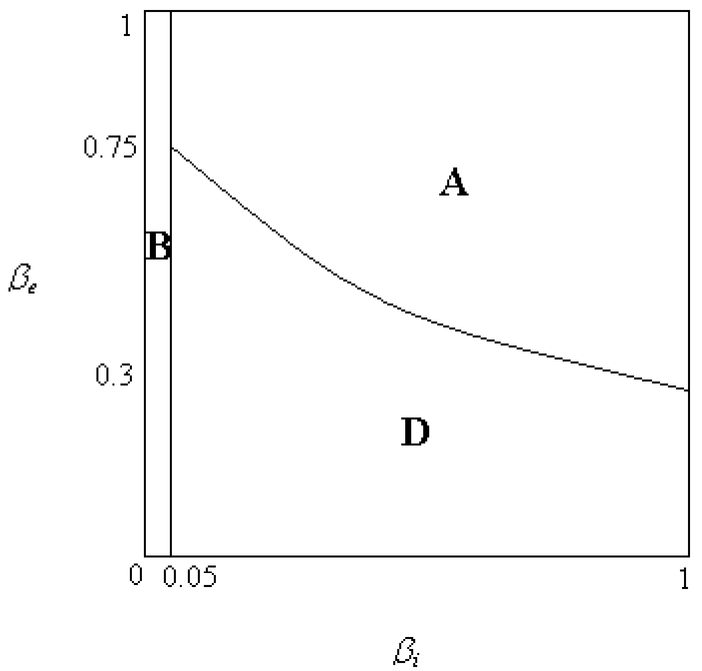
γ=0.0005, π^d=13500, π^m=15000, S=100, β_i=0.1, β_e=0.5

Figure 4. Equilibrium profits: $F_{AD} < F_x$



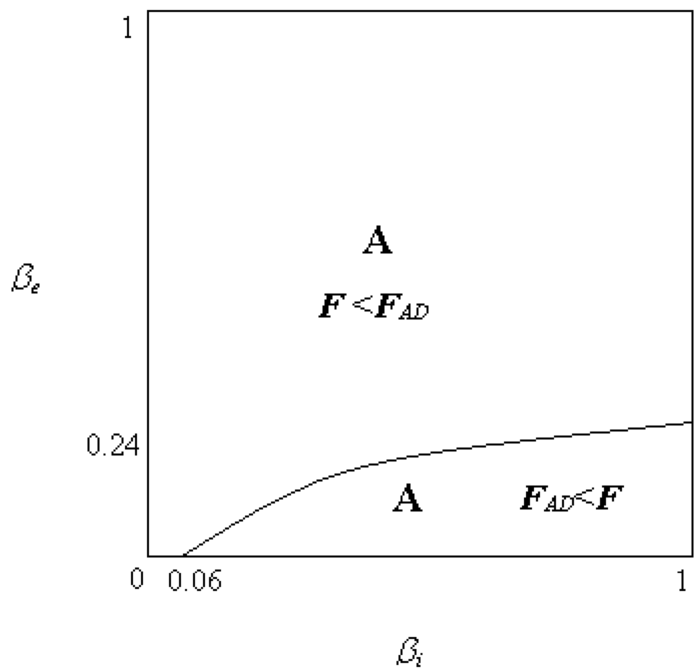
γ=0.0005, π^d=10000, π^m=15000, S=100, β_i=0.1, β_e=0.1

Figure 5. Equilibrium outcomes: $F > F_x$



F=14500, γ=0.0005, π^d=13500, π^m=15000, S=100

Figure 6. Equilibrium outcomes: $F < F_x$



F=14375, γ=0.0005, π^d=13500, π^m=15000, S=100