Excess Absorptive Capacity and the Persistence of Monopoly

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Abstract

We consider a monopolist's precommitment to imitate a potential entrant's innovation by means of entry deterrence. This precommitment, i.e. excess absorptive capacity, always decreases the entrant's efforts to innovate whereas it increases (decreases) the monopolist's efforts if potential duopoly profits are low (high). If potential competition is à la Bertrand, a certain degree of excess absorptive capacity indeed suffices to render the monopolist more innovative than the entrant, since even if the innovation is drastic, monopoly would tend to persist. More excess absorptive capacity increases the monopolist's equilibrium payoff whereas it decreases the entrant's.

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1 Introduction

In high-tech industries the persistence of dominant, monopolistic firms can be explained by superior innovative performance of the monopolist relative to a potential entrant. Superior performance, in turn, follows greater incentives to invest in new products or processes. Accordingly, market structure in high-tech industries is tied to the question whether it is the incumbent or the entrant who has greater incentives to innovate. Arrow (1962), Gilbert and Newberry (1982) and Reinganum (1983) provide seminal answers based on asymmetries in the monopolist's and the potential entrant's returns from a succesful innovation (see below). Numerous refinements[1] of these early works argue that an incumbent's initial technological lead or some kind of precommitment to innovate (Etro 2004) reduces an entrant's incentives to innovate and induces the persistence of monopoly respectively.

As an alternative explaination we consider how an incumbent's precommitment to *imitate* preserves its dominant position. The idea is based on the fact that innovations, in general, are subject to knowledge spillovers[2] whereby the receipient needs to have absorptive capacity, i.e. the "ability to identify, assimilate, and exploit knowledge from the environment and to apply it to commercial ends" (Cohen and Leventhal 1989 and 1990). Our central assumption is that an incumbent rather than an entrant has built up and maintains such a capacity, either simply as a by-product of previous R&D or, somewhat more purposely, by means of basic research (Rosenberg 1990) and "large numbers of small and apparently unproductive [research] programs" (Henderson and Cockburn 1996). In either case some costs of imitation are sunk. This precommitment to imitate constitutes a credible (counter-) threat to the entrant's innovative threat.

Apperantly a monopolist only needs absorptive capacity to affect potential competition. We highlight the strategic dimension with the notion of absorptive capacity in *excess* to the amount needed if there were no potential competition (i.e. zero absorptive capacity[3]).

[1] See Tirole (1988), chapter 10, for an overview.

[2] See Griliches (1992) for an overview.

[3] Needless to say, this picture is highly stylized in the sense that a monopolist which is not threatened by entry may still benefit from an absorptive capacity due to knowledge

To illustrate the idea of excess absorptive capacity, consider Microsoft's reaction to Netscape's competitive threat. According to case evidence provided by Klein (2001) Microsoft's browser, Internet Explorer, was clearly inferior to Netscape's Navigator during 1995-96[4]. But "during 1995-97, Microsoft devoted more than $ 100 million per year to browser software development", and in September 1997 Microsoft achieved superiority in internet browser technology with the release of Internet Explorer 4.0. Apparently Microsoft not only possessed the absorptive capacity to catch up with the progress in browser technology but also had stronger investment incentives to develop the superior and hence eventually successful browser[5].

In light of the initially cited theories on incentives to innovate, Microsoft's massive investments are indeed surprising. Following Gilbert and Katz (2001) the battle between Microsoft and Netscape was essentially about establishing a programming platform; in particular Navigator was a distribution vehicle for Java and server based applications whereas Internet Explorer was linked to Windows. Due to network effects the dominant programming platform would in turn promote the persistence of Microsoft's monopoly or the creation of new monopoly, respectively. Hence, in the terminology of Reinganum (1983), the innovation at stake was drastic (no efficiency effect) such that the entrant, Netscape, should have invested more than the incumbent[6]. At the same time Arrow's (1962) replacement effect might have arguably been strong due to Microsoft's comfortable returns from Windows whereas Netscape possessed the initial technological advantage, which, again, supports less investments by the incumbent Microsoft.

How does excess absorptive capacity help to explain this investment be-

spillovers from research institutes or universities. We abstract from such linkages for the sake of simplicity.

[4]The quality evaluation of Internet Explorer and Navigator was based on the share of "wins" in three independent computer magazines.

[5]Microsoft's success in the battle with Netscape has been primarily related to its aggressive (zero) pricing of Internet Explorer and its tying of Internet Explorer to Windows. Klein (2001), however, reports that it was not before Microsoft had a comparable product available until Internet Explorer's usage began to increase.

[6]Even if one argued that the development of the internet browser technology was deterministic rather than uncertain the Gilbert and Newberry (1982) model would predict at least innovation efforts of equal size.

havior? And to which degree does it benefit (hurt) the incumbent (entrant)? These are the questions we seek to answer in this paper. In particular we set up a model in which the incumbent maintains excess absorptive capacity. It is measured by the probability of an immediate imitation of an entrant's innovation. Knowing this probability firms choose their investments to innovate under uncertainty.

With respect to the first question, we show that excess absorptive capacity reduces the entrant's innovation investments and has two effects on the incumbent's investments. On the one hand it induces an *aggressive innovation effect*: deterring the entrant's innovation efforts increases the profitability of the incumbent's investments. On the other hand excess absorptive capacity creates a *copycat effect*, countervailing the former: an incumbent reduces its own innovation efforts to free ride on a successful innovation by the entrant. The copycat effect vanishes if profits in post innovation competition approach zero (i.e. Betrand competition). Then the aggressive innovation effect might indeed be sufficiently strong to guarantee more innovation efforts by the incumbent; even, as illustrated above, if the innovation is drastic (as defined by Reinganum 1983) and the incumbent replaces, for the most part, itself (Arrow 1962). These findings are consistent with the (scarce) empirical evidence on innovation behavior by incumbents and entrants[7].

The second question, i.e. in how far excess absorptive capacity benefits (hurts) the incumbent (entrant), is related to Cohen and Levinthal's (1994) analysis of a monopolist's incentives to invest in absorptive capacity. In contrast to our work their model presumes that a monopolist's investment in absorptive capacity creates a public good to be shared with potential entrants, namely expectations of the success of a technology. As criticized by Joglekar et al. (1997), their model omits "one critical element of absorptive capacity, namely a firm's ability to defend itself against the threat of external technology". Whereas Joglekar et al. (1997) "never indicate how

[7] Blundell and Griffith (1999) find a positive relationship between innovation and market share (to reflect incumbency) as well as between innovation and a firm's knowledge stock. In contrast Czarnitzki and Kraft (2004) find entrants more likely to innovate which might be due to the fact that they employ a *relative* measure for innovativeness: the R&D-to-sales ratio. Our model, however, aims to explain *absolute* incentives to innovate.

their alternative specifications change [Cohen and Levinthal's] results"[8], our model adresses this question. Excess absorptive capacity clearly mimics such a defense capability and we find it to increases (decrease) the incumbent's (entrant's) equilibrium payoff[9].

The paper is organized as follows. Section 2 presents a description of the model. In section 3 we analyze how (a given) excess absorptive capacity affects the incumbent's and the entrant's incentives to innovate. In particular we start with the simple case of post-innovation Betrand competition and then extend our findings to the general case in which a post-innovation duopoly is profitable. Building on the results of 3, section 4 analyzes an incumbent's incentives to build up excess absorptive capacity. We first investigate the change of the firms' equilibrium payoffs due to excess absorptive capacity and then establish its absolute (maximum) value. Section 5 draws a conclusion.

2 The model

We consider a two stage setting. In the first stage only the incumbent, I, exists and builds up an absorptive capacity. Subsequently, in stage two, I and the (potential) entrant, E, decide simultaneously on their efforts/investments to obtain an innovation under uncertainty. A successful innovation advantages the innovator in terms of lower production costs (process-innovation) or enhanced product quality (product-innovation); either interpretation is suitable. We propose that innovations cannot be fully protected by patents which means that both firms can innovate successfully and that innovations can be imitated. Imitation, however, does not occur automatically in the sense of spillovers like 'manna from heaven', but requires absorptive capacity, the "ability to identify, assimilate, and exploit knowledge from the environment and to apply it to commercial ends" (Cohen and Levinthal 1989, 1990).

For simplicity we normalize the entrant's absorptive capacity to zero,

[8] Cohen and Levinthal's (1997) reply to Joglekar's et al. "Comments on 'Fortune Favors the Prepared Firm'".

[9] We also establish a small parameter range in which excess absorptive capacity in fact increases the entrant's equilibrium payoff (see section 4 for details).

whereas the incumbent's absorptive capacity is measured by the probability, β_I, $0 \leqslant \beta_I \leqslant 1$, of an immediate imitation of a potential entrant's innovation. In the innovation stage the level of β_I is given and common knowledge. Furthermore we follow Rosen (1991) and Kannianen and Stenbacka (2000) in modelling innovation efforts directly through the probability of a successful innovation by the incumbent, α_I, $0 \leqslant \alpha_I \leqslant 1$, and the entrant, α_E, $0 \leqslant \alpha_E \leqslant 1$, respectively. The firms thus determine α_I and α_E and bear innovation costs of the form $(a/2)\alpha_I^2$ and $(a/2)\alpha_E^2$.

The firms' payoffs depend on which one of them possesses the innovation. If none of the firms innovate successfully, the incumbent receives $\pi^M(\overline{c})$, the monopoly profits given the old technology. If only the incumbent innovates it gets $\pi^M(\underline{c})$, monopoly profits for the new technology, and if both the incumbent and the entrant innovate then each firm earns π^D, duopoly profits. If only the entrant innovates it obtains leader profits, π^L, provided the incumbent does not manage to imitate and the duopoly profit, π^D, if the incumbent does imitate. In the case of a sole innovation by the entrant, the incumbent obtains follower profits, π^F, if it does not manage to catch up with the entrant and the duopoly profit, π^D, if it imitates the entrant's innovation. We assume $\pi^L > \pi^D \geqslant \pi^F \geqslant 0$ with equality only if competition is a la Betrand and $\pi^M(\underline{c}) \geqslant \pi^L$ with equality only if the innovation is drastic. Hence, the incumbent's and the entrant's pay-off functions can be written as

$$\begin{aligned} V_I &= \alpha_I(1-\alpha_E)\pi^M(\underline{c}) + \alpha_I\alpha_E\pi^D + (1-\alpha_I)(1-\alpha_E)\pi^M(\overline{c}) \\ &\quad +(1-\alpha_I)\alpha_E\beta_I\pi^D + (1-\alpha_I)\alpha_E(1-\beta_I)\pi^F - (a/2)\alpha_I^2, \end{aligned} \tag{1}$$

and, respectively,

$$V_E = \alpha_E(1-\alpha_I)(1-\beta_I)\pi^L + \alpha_E\alpha_I\pi^D + \alpha_E(1-\alpha_I)\beta_I\pi^D - (a/2)\alpha_E^2. \tag{2}$$

The more excess absorptive capacity, β_I, the more likely the incumbent will get π^D instead of π^F by (1) and the more likely the entrant will only earn π^D instead of π^L by (2).

3 Incentives to innovate (2nd stage)

In section 3 we seek answers to the following questions. First, how does excess absorptive capacity change the incumbent's and the entrant's equilibrium innovation efforts? Secondly we investigate which of the firms induces more innovation efforts in absolute terms and, as a consequence, is more likely to dominate the post-innovation market. In doing so we start with case of potential Betrand competition in section 3.1. In this case there exists only one effect of excess absorptive capacity, namely the aggressive innovation effect. In the more general and complicated case of non-Betrand competition (section 3.2) an additional (copy-cat) effect alters our results.

In the second stage the incumbent maximizes (1) with respect to α_I and the entrant (2) with respect to α_E, given the incumbent's excess absorptive capacity, β_I. The first-order-conditions are

$$\frac{\partial V_I}{\partial \alpha_I} = (1-\alpha_E)(\pi^M(\underline{c}) - \pi^M(\overline{c})) + \alpha_E(1-\beta_I)(\pi^D - \pi^F) - a\alpha_I = 0 \quad (3)$$

and

$$\frac{\partial V_E}{\partial \alpha_E} = (1-\alpha_I)(1-\beta_I)\pi^L + (\beta_I(1-\alpha_I)+\alpha_I)\pi^D - a\alpha_E = 0. \quad (4)$$

To assure concavity of the profit functions (1) and (2) in α_I and α_E we propose $a > \pi^M(\underline{c})$. By (3) and (4) this assumption also guarentees an interior solution to the firms' maximization problem, i.e. $\alpha_I < 1$ and $\alpha_E < 1$. The interpretation of this technically reasoned assumption is that innovation projects are such complex that firms never find it optimal to induce as much efforts as to guarantee a succussful innovation, i.e. $\alpha_I = 1$ and $\alpha_E = 1$.

3.1 Bertrand competition and the aggressive innovation effect

In the case of potential Betrand competition we have $\pi^D = \pi^F = 0$. Let α_I^r and α_E^r denote the incumbent's and the entrant's reaction-funtion as implied by (3) and (4), then

$$\alpha_I^r = (1-\alpha_E)(\pi^M(\underline{c}) - \pi^M(\overline{c}))/a \quad (5)$$

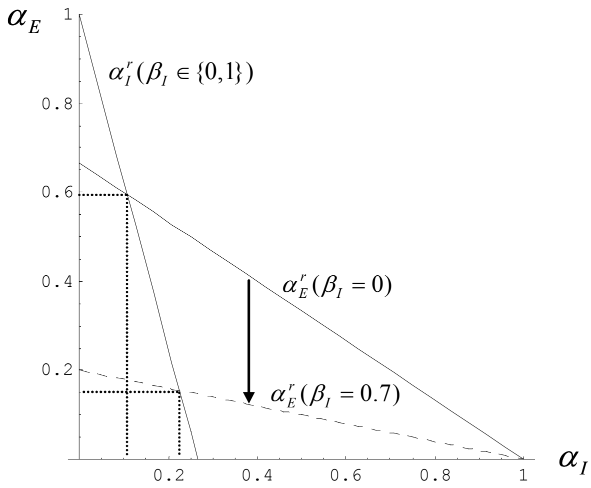

Figure 1: Reaction functions with/out preemptive absorptive capacity ($\beta_I = 0.7$ / $\beta_I = 0$); $a = 15$, $\pi^M(\underline{c}) = \pi^L = 10$, $\pi^M(\overline{c}) = 6$.

and

$$\alpha_E^r = (1 - \alpha_I)(1 - \beta_I)\pi^L / a. \tag{6}$$

By (5), α_I^r is independent of β_I and thus excess absorptive capacity has no direct effect on the incumbent's optimal innovation efforts. Due to (6), however, the entrant's optimal innovation efforts are decreasing in β_I. Since (5) and (6) imply that the firms' decision variables are strategic substitutes as defined by Bulow et al. (1984), i.e. $\partial\alpha_I^r(\alpha_E)/\partial\alpha_E < 0$ and $\partial\alpha_E^r(\alpha_I)/\partial\alpha_I < 0$, the decrease of the entrant's efforts causes an increase of the incumbent's equilibrium innovation efforts (see Figure 1).

The change of equilibrium innovation efforts in excess absorptive capacity We solve (3) and (4) simultaneously for α_I and α_E and get the incumbent's equilibrium innovation efforts,

$$\alpha_I^* = \frac{(\pi^M(\underline{c}) - \pi^M(\overline{c}))(a - (1 - \beta_I)\pi^L)}{a^2 - (1 - \beta_I)(\pi^M(\underline{c}) - \pi^M(\overline{c}))\pi^L}, \tag{7}$$

as well as the entrant's equilibrium efforts,

$$\alpha_E^* = \frac{(1 - \beta_I)(a - (\pi^M(\underline{c}) - \pi^M(\overline{c}))\pi^L}{a^2 - (1 - \beta_I)(\pi^M(\underline{c}) - \pi^M(\overline{c})\pi^L}. \tag{8}$$

Then, differentiating (7) and (8) with respect to β_I yields

$$\frac{\partial \alpha_I^*}{\partial \beta_I} = \frac{a(a-(\pi^M(\underline{c})-\pi^M(\overline{c})))(\pi^M(\underline{c})-\pi^M(\overline{c}))\pi^L}{(a^2-(1-\beta_I)(\pi^M(\underline{c})-\pi^M(\overline{c}))\pi^L)^2} > 0, \tag{9}$$

and

$$\frac{\partial \alpha_E^*}{\partial \beta_I} = -\frac{a^2(a-(\pi^M(\underline{c})-\pi^M(\overline{c}))\pi^L}{(a^2-(1-\beta_I)(\pi^M(\underline{c})-\pi^M(\overline{c}))\pi^L)^2} < 0, \tag{10}$$

and we can state[10]

Proposition 1 *Aggressive innovation effect: if $\pi^D = \pi^F = 0$, excess absorptive capacity increases the incumbent's and decreases the entrant's efforts to innovate.*

Proof. Straightforward by (9) and (10).

Excess absorptive capacity acts as a *complement* to an incumbent's innovation efforts. The incumbent's absorptive capacity reduces the probability that entrant captures, after a successful innovation, the profits of a cost-leader, π^L, which decreases the marginal profitability of the entrant's innovation efforts. The reduction of the entrant's innovation efforts in turn increases the probability of an unique innovation by the incumbent which secures monopoly profits, $\pi^M(\underline{c})$. It is worth emphasizing that here excess absorptive capacity has the purely strategic value of deterring an entrant's innovation (and entry, respectively). The incumbent itself gains nothing from its absorptive capacity, i.e. $\pi^D = 0$, once the entrant has in fact innovated.

Which firm will innovate with a higher probability? Note that (7) and (8) have identical denominators and hence, by the numerators, $\alpha_I^* - \alpha_E^* < 0$ if and only if

$$\pi^M(\underline{c}) - \pi^M(\overline{c}) - (1-\beta_I)\pi^L < 0, \tag{11}$$

which implies the following

Proposition 2 *If $\pi^D = \pi^F = 0$, the entrant innovates with a higher probability than the incumbent, $\alpha_E^* > \alpha_I^*$, if and only if*

$$\beta_I < \frac{\pi^L - (\pi^M(\underline{c}) - \pi^M(\overline{c}))}{\pi^L}.$$

[10] Further comparative statics of α_I^* and α_E^* are discussed for the more general case in section 3.2.

There exists a 'limit absorptive capacity' in the sense that $\alpha_E^* = 0$ *if and only if* $\beta_I = 1$.

Proof. Straightforward by (11) (first claim) and (8) (second claim).

The term $\pi^M(\underline{c}) - \pi^M(\overline{c})$ reflects Arrow's (1962) replacement effect: the larger the extent to which the incumbent only replaces its old profit stream with the new one, the less are its incentives to innovate relative to an entrant. In this sense we will refer to a *stronger* replacement effect the closer $\pi^M(\overline{c})$ is to $\pi^M(\underline{c})$. As pointed out by Gilbert and Newberry (1982), however, the potential entrant suffers from the fact that it would, unlike the incumbent, not monopolize the post-innovation market. This so-called efficiency effect vanishes if the innovation is drastic, $\pi^L = \pi^M(\underline{c})$. Reinganum (1983) has established that a sufficiently drastic innovation and uncertainty in the innovation process indeed render the entrant more innovative than the incumbent. Inequality (11) confirms this if $\beta_I = 0$ but the introduction of excess absorptive capacity puts this result into perspective:

Corollary 1 *In the case of a drastic innovation,* $\pi^L = \pi^M(\underline{c})$, *the entrant innovates with a higher probability than the incumbent if and only if*

$$\beta_I < \frac{\pi^M(\overline{c})}{\pi^M(\underline{c})}.$$

As long as the incumbent builds up an absorptive capacity that makes the probability of an immediate imitation larger than the ratio between ex ante and ex post innovation monopoly profits, the incumbent innovates with a higher probability than the entrant. By Proposition 2 it follows, moreover, that a more drastic innovation only increases an entrant's incentives to innovate (relative to the incumbent's) if $\pi^L < \pi^M(\underline{c})$. In contrast Corollary 1 implies that once we have $\pi^L = \pi^M(\underline{c})$, an even more radical innovation increases the likelihood that the incumbent induces more efforts to innovate than the entrant, which is true whenever $\beta_I \pi^M(\underline{c}) > \pi^M(\overline{c})$. This would not occur without excess absorptive capacity.

3.2 Non-Bertrand and the Copycat-Effect

Consider now the more general case of $\pi^D > 0$ and $\pi^F > 0$, a setting that would reflect, for instance, Cournot competition or Betrand competition with differentiated products. The first-order-conditions (3) and (4) then imply reaction functions of the form

$$\alpha_I^r = \left[(1-\alpha_E)(\pi^M(\underline{c}) - \pi^M(\overline{c})) + \alpha_E(1-\beta_I)(\pi^D - \pi^F)\right]/a, \tag{12}$$

and

$$\alpha_E^r = \left[(1-\alpha_I)(1-\beta_I)\pi^L + (\beta_I(1-\alpha_I) + \alpha_I)\pi^D\right]/a. \tag{13}$$

In contrast to (5), by (12) an increase in excess absorptive capacity also changes the incumbent's reaction curve, i.e. turning it inwards as displayed by Figure 2. This effect is stronger the larger the probability of a successful innovation by the entrant, α_E. Since the post-innovation duopoly is profitable, substituting an own innovation through an imitation of the entrant's innovation becomes attractive and creates a *copycat-effect* of excess absorptive capacity, countervailing the aggressive innovation effect. The aggressive innovation effect is indeed still apparent as can be easily checked by $\partial\alpha_E^r/\partial\beta_I = -(1-\alpha_I)(\pi^L - \pi^D)/a \leqslant 0$ whereby the firms' innovation efforts remain strategic substitutes to each other, e.g. $\partial\alpha_I^r/\partial\alpha_E \leqslant 0$ as long as $(\pi^M(\underline{c}) - \pi^M(\overline{c})) > (1-\beta_I)(\pi^D - \pi^F)$. Throughout we focus on the case in which the latter inequality indeed holds. It will in fact hold if potential competition is a la Cournot with linear demand (see example below)[11].

The occurrence of the copycat-effect raises two questions. First, under which conditions does it dominate the aggressive innovation effect, such that, as displayed by Figure 2, excess absorptive capacity decreases the incumbent's efforts to innovate instead of increasing them. Secondly, how does the copycat-effect change our predictions whether it is the incumbent or the entrant who has greater incentives to innovate. To deal with these questions it is convenient to have the following intermediate result at hand:

Lemma 1 *There exists a unique, stable Nash equilibrium* (α_I^*, α_E^*)*, in which (a) the incumbent's innovation efforts,* α_I^**, are increasing in* $\pi^M(\underline{c})$ *and decreasing in* $\pi^M(\overline{c})$*,* π^L*,* π^D *and* π^F*,*

[11] This assumption could be potentially critical for the proof of the derivative of α_I^* with respect to π^D and π^L in Lemma 1 and the proof of the first claim of Proposition 5. An obvious application of $\pi^M(\underline{c}) - \pi^M(\overline{c}) < \pi^D - \pi^F$, would be a strong replacement-effect and limit pricing by the entrant, $\pi^F = 0$.

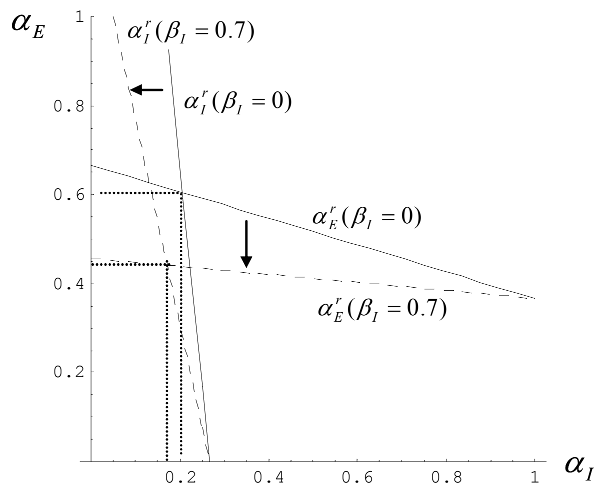

Figure 2: Reaction functions with/out preemptive absorptive capacity ($\beta_I = 0.7$ / $\beta_I = 0$); $a = 15$, $\pi^M(\underline{c}) = \pi^L = 10$, $\pi^M(\overline{c}) = 6$, $\pi^D = 5.5$, $\pi^F = 3$.

(b) the entrant's innovation efforts, α_E^*, are decreasing in $\pi^M(\underline{c})$ and increasing in $\pi^M(\overline{c})$, π^L, π^D and π^F.

Proof. See Appendix.

The logic behind Lemma 1 can be deduced from a firm's individual incentive to innovate and the fact that innovation efforts are strategic substitutes. In particular an increase in $\pi^M(\underline{c})$ increases the profit stream the incumbent gets on top of its current monopoly profits, $\pi^M(\overline{c})$. Hence the incumbent invests more and, as a consequence of the strategic substitutability, the entrant less. The same logic applies for an increase in π_L and $\pi^M(\overline{c})$. The entrant increases its innovation efforts if π^D gets larger because in the case of a profitable post-innovation duopoly it profits from its innovation even if the incumbent also innovates or imitates. The increase of α_E^* in π^D again causes α_I^* to decrease in π^D. In order to understand the change of α_I^* in π^F note the incumbent's incentives to innovate are not only driven by the profit it gains from an innovation if the entrant does not innovate, $\pi^M(\underline{c}) - \pi^M(\overline{c})$, but also by the probability to obtain π^D rather than π^F if the entrant innovates successfully. Hence the larger the incumbent's profits as a follower the smaller its incentives to innovate with the purpose to get π^D instead of π^F.

The change of the entrant's probability to innovate, α_E^*, with respect to an increase in the follower's profits is, once again, caused by the fact that α_I and α_E are strategic substitutes.

How do equilibrium innovation efforts change in excess absorptive capacity? With respect to the incumbent it is helpful to assume $\beta_I = 0$ for a second and to think of two sources that create its incentives to innovate. First the incumbent seeks to earn incremental monopoly profits $\pi^M(\underline{c}) - \pi^M(\overline{c}) > 0$ in the case the entrant does not innovate successfully. Secondly, in case the entrant is successful, the incumbent's own innovation still secures incremental profits $\pi^D - \pi^F > 0$ as compared to profits from the old technology/product, π^F. Now, excess absorptive capacity, $\beta_I > 0$, works as a substitute to the incumbent's own innovation in achieving the latter benefit, $\pi^D - \pi^F$, which is attainable, just as well, through an imitation. In contrast excess absorptive capacity complements the incumbent's own innovation to accomplish $\pi^M(\underline{c}) - \pi^M(\overline{c})$ by discouraging the entrant from innovating. In essence, the incumbent adopts a copycat (aggressive innovation) stratagy if the substitutional (complementary) effects domitate. We state this more precisely in

Proposition 3 *(a) Dominance of the copycat effect: excess absorptive capacity decreases the incumbent's efforts to innovate, $\partial\alpha_I^*/\partial\beta_I < 0$, if*

$$\frac{\pi^M(\underline{c}) - \pi^M(\overline{c})}{\pi^D - \pi^F} + 2\beta_I \leqslant \frac{\pi^L}{\pi^L - \pi^D} + 1.$$

(b) Excess absorptive capacity decreases the entrant's efforts to innovate, $\partial\alpha_E^*/\partial\beta_I < 0$.

Proof. See Appendix.

As long as the weak inequality in Proposition 3 is satisfied we are guaranteed that, in contrast to Proposition 1, excess absorptive capacity *substitutes* an incumbent's efforts to innovate. Even though the reverse statement to Proposition 3 does not follow immediately if the inequality is not true we focus on this restricted case as it still captures the main economic logic.

The left- (LHS) and the right-hand-side (RHS) of the inequality in Proposition 3 balances the strengths of the complementary or substitutional effects as caused by exogenous (market and technological) conditions. In particular the LHS accounts for the conditions that directly affect the incumbent's innovation incentives as scetched above. Accordingly the larger $(\pi^D - \pi^F)$ relative to $(\pi^M(\underline{c}) - \pi^M(\overline{c}))$ the more likely the incumbent will adopt a copycat strategy and cut back on own innovation efforts as a consequence its absorptive capacity.

The RHS takes into account the entrant's incentives to innovate and, as a consequence, the relative effectiveness of a copycat or aggressive innovation strategy by the incumbent. Note first that large leader profits π^L increase an entrant's incentives to innovate. This makes outspending the entrant on R&D rather expensive but free-riding on the entrant's (likely) success attractive: the incumbent rather adopts a copycat strategy. On the other hand $\pi^L - \pi^D$ measures the effectiveness of excess absorptive capacity in order to induce an aggressive innovation strategy: the larger the gap between π^L and π^D, the more will the incumbent's absorptive capacity discourage an entrant's innovation which increases the likelihood that the incumbent gets $\pi^M(\underline{c})$ rather than π^D after an own successful innovation. This in turn renders the incumbent's innovation efforts more profitable. The lower $\pi^L - \pi^D$ the more likely we have that the incumbent adopts a copycat strategy.

The effect of β_I in the inequality can be explained as follows. The larger the incumbent's absorptive capacity the lower are by part *(b)* the entrant's incentives to innovate. Then it is in fact unlikely that the entrant will be successful at all and hence a copycat strategy becomes less attractive.

Given the fact that a potential entrant's efforts to innovate always decrease in excess absorptive capacity whereas the incumbent's efforts may either increase or decrease the question on the net effect of these changes is apparent. We provide the answer in

Proposition 4 *Excess absorptive capacity decreases the firms' overall innovation efforts,* $\partial(\alpha_I^* + \alpha_E^*)/\partial\beta_I < 0$.

Proof. See Appendix.

Which firm will innovate with a higher probability? In the general case of $\pi^D > 0$ and $\pi^F > 0$ the respective result to Proposition 2 is

Proposition 5 *The entrant innovates with a higher probability than the incumbent, $\alpha_E^* > \alpha_I^*$, if*

$$\beta_I < \frac{\pi^L - (\pi^M(\underline{c}) - \pi^M(\overline{c}))}{\pi^L - \pi^D}.$$

The higher β_I the more likely we have $\alpha_I^* > \alpha_E^*$ and $\beta_I = 1 \Longrightarrow \alpha_E^* = (\pi^D/a)$, i.e. there exists no 'limit absorptive capacity'.

Proof. See Appendix.

Proposition 5 confirms the main qualitative result of Proposition 2: the higher the excess absorptive capacity of the incumbent the less likely can we guarantee that $\alpha_E^* > \alpha_I^*$. The difference to Proposition 2 is that condition Proposition 5 depends also on post-innovation duopoly profits, π^D. The denominator reflects, again, how effective an incumbent's absorptive capacity works as a barrier to innovation and to entry respectively. If and only if the gap between the entrant's profit as a cost-leader, π^L, and the duopoly profit, π^D, gets sufficiently large, excess absorptive capacity can threaten the entrant such that it incurs less efforts to innovate than the incumbent.

An example: Potential Cournot Competition with linear demand and constant marginal costs As yet the results stated in Propositions 4 and 5 are not linked to a particular type of product market competition. This raises the question in which relation the particular profit differences may stand to each other for a given type of competition and innovation size. As an example we consider the case of Cournot competition with linear demand, $a - bQ$, where $Q = q_I + q_E$ in the case we calculate π^L, π^D, π^F, and $Q = q_I$ if we calculate $\pi^M(\underline{c})$, $\pi^M(\overline{c})$. We suppose, moreover, constant marginal costs of production, $c - x_i$, $i = I, E$, where $x_i \leqslant a - c$ measures the size of the i'th firm's process-innovation. Note that for π^F, $\pi^M(\overline{c})$ we have $x = 0$. Straightforward algebra, which is omitted for brevity, reveals that the following relations hold depending on the size of the innovation, x:

$$\begin{aligned}
\text{minor innovation} &: \pi^L - \pi^D < \pi^D - \pi^F < \pi^M(\underline{c}) - \pi^M(\overline{c}) < \pi^L \\
\text{major innovation} &: \pi^D - \pi^F < \pi^L - \pi^D < \pi^M(\underline{c}) - \pi^M(\overline{c}) < \pi^L \\
\text{radical innovation} &: \pi^D - \pi^F < \pi^M(\underline{c}) - \pi^M(\overline{c}) < \pi^L - \pi^D < \pi^L.
\end{aligned}$$

The example suggests that it is in particular $(\pi^L - \pi^D)$ which increases in the size of the innovation. If the innovation is minor then $(\pi^L - \pi^D) < (\pi^D - \pi^F)$ and the incumbent will rather adopt the copycat strategy. However if the innovation, x, exceeds a certain degree we have $(\pi^L - \pi^D) > (\pi^D - \pi^F)$ and eventually even $(\pi^L - \pi^D) > (\pi^M(\underline{c}) - \pi^M(\overline{c}))$. By Proposition 3 then drastic innovations rather induce an aggressive innovation strategy by the incumbent and, as confirmed by Proposition 5, monopoly tends to persist in these cases.

4 Incentives to build up excess absorptive capacity

Thus far we have left open the question of how much absorptive capacity will be built up by an incumbent. In seeking an answer to that problem the difficulty of setting up an appropriate cost measure for absorptive capacity arises. As mentioned before a firm may build up absorptive capacity partly as a byproduct of previous research and partly through specific, extra investments. In our basic model, therefore, we abstract from such specific costs and restrict our attention to the direct and strategic effects, excess absorptive capacity has on the incumbent's and the entrant's equilibrium payoffs. Needless to say, the incumbent's benefits from absorptive capacity would have to be traded off against the respective costs of building it up.

The incumbent's equilibrium payoff We differentiate the incumbent's expected value V_I with respect to β_I,

$$\frac{dV_I}{d\beta_I} = \frac{\partial V_I}{\partial \beta_I} + \frac{\partial V_I}{\partial \alpha_I}\frac{d\alpha_I^*}{d\beta_I} + \frac{\partial V_I}{\partial \alpha_E}\frac{d\alpha_E^*}{d\beta_I}, \tag{14}$$

where $\partial V_I/\partial \alpha_I = 0$ by the second stage maximization problem (enveloppen theorem) and $d\alpha_E^*/d\beta_I = \partial \alpha_E^*/\partial \beta_I$ as given by Proposition 3. We are thus left with the direct effect $\partial V_I/\partial \beta_I$ and the strategic effect $(\partial V_I/\partial \alpha_E)(d\alpha_E^*/d\beta_I)$. Calculating the respective derivatives from (1) and substituting these into (14) yields

$$\frac{dV_I}{d\beta_I} = \underbrace{\alpha_E^*(1-\alpha_I^*)(\pi^D - \pi^F)}_{\textit{direct copycat effect, } >0} \tag{15}$$
$$-\underbrace{\left[\alpha_I^*\underbrace{(\pi^M(\underline{c}) - \pi^D)}_{\textit{success benefit}} + (1-\alpha_I^*)\underbrace{(\pi^M(\overline{c}) - \beta_I\pi^D - (1-\beta_I)\pi^F)}_{\textit{failure benefit}}\right]\underbrace{\frac{d\alpha_E^*}{d\beta_I}}_{<0}}_{\textit{strategic deterrence effect, } >0}.$$

According to (15) more absorptive capacity benefits the incumbent for two reasons. As indicated by the first effect, the incumbent firm profits directly because it receives π^D rather than π^F if only the entrant innovates successfully. On the other hand more absorptive capacity also benefits the incumbent for strategic reasons: decreasing the entrant's incentives to innovate, $\partial\alpha_E^*/\partial\beta_I < 0$, pays off because the incumbent firm then receives $\pi^M(\underline{c}) > \pi^D$ if it innovates successfully and $\pi^M(\overline{c}) > \beta_I\pi^D + (1-\beta_I)\pi^F$ if it fails to innovate. This positive strategic effect indicates that an incumbent over-invests in its absorptive capacity[12]. Without costs of absorptive capacity V_I is indeed maximized for $\beta_I = 1$.

The entrant's equilibrium payoff Proceeding in a similar fashion as above, we have

$$\frac{dV_E}{d\beta_I} = \frac{\partial V_E}{\partial \beta_I} + \frac{\partial V_E}{\partial \alpha_E}\frac{d\alpha_E^*}{d\beta_I} + \frac{\partial V_E}{\partial \alpha_I}\frac{d\alpha_I^*}{d\beta_I}, \tag{16}$$

where, by the same argument as above, $\partial V_E/\partial\alpha_E = 0$ and $d\alpha_I^*/d\beta_I = \partial\alpha_I^*/\partial\beta_I$ as given by Proposition 3. Calculating the respective derivatives from (2) and rearranging terms slightly gives

$$\frac{dV_E}{d\beta_I} = -\alpha_E^*(\pi^L - \pi^D)\left[(1-\alpha_I^*) + (1-\beta_I)\frac{d\alpha_I^*}{d\beta_I}\right] < 0. \tag{17}$$

If the entrant innovates successfully more absorptive capacity changes its expected value by $(\pi^L - \pi^D)$ conditional on the two terms in the squared

[12] Benoit and Krishna (1991) show that preemptive capacity may facilitate entry in dynamic competition by increasing competitive intensity and, as a consequence, making a collusive outcome more sustainable. Hence if post-innovation competition is dynamic and preemptive absorptive capacity increases competitive intensity one might derive different conclusions regarding the incumbent's incentives to over-invest.

bracketed term. The first one refers to a direct effect: for any given probability that the incumbent does not *innovate* successfully, $(1-\alpha_I^*)$, an additional unit of excess absorptive capacity still facilitates that the entrant does not get π^L instead of π^D. The second term in contrast indicates that for any given probability that the incumbent does not *imitate* successfully, $(1-\beta_I)$, excess absorptive capacity still affects the entrant's expected value as it changes the incumbent's innovation behavior. By Proposition 3 $d\alpha_I^*/d\beta_I$ may be either positive or negative but (as shown in the proof of Proposition 7) if $d\alpha_I^*/d\beta_I < 0$, the direct effect still dominates the strategic effect, i.e. $(1-\alpha_I^*)+(1-\beta_I)(\partial\alpha_I^*/\partial\beta_I) > 0$. Thus also by means of entry deterrence the incumbent unambiguously gains from its absorptive capacity. We summarize these considerations in

Proposition 6 *Excess absorptive capacity increases the incumbent's payoff (entry accommodation case) and decreases the entrant's payoff (entry deterrence case)[entry deterrence case to be revised].*

Proof. See appendix.

5 Conclusion

As an alternative to studies that focus on how an incumbent's superior ability to innovate preserves its dominant position , this paper analyzes an incumbent's superior ability to imitate, i.e. its excess absorptive capacity, as a means of deterring an external innovation and entry respectively. The concept of excess absorptive capacity allows to relax assumptions of initial technological leads by the incumbent as well as first-mover-advantages in innovation. Yet even without these assumptions our results indicate that monopoly tends to persist. First we show that excess absorptive capacity always decreases the entrant's incentives to innovate whereas it increases (decreases) the incumbent's incentives if potential duopoly profits are low (high). In any case a larger excess absorptive capacity ensures that the incumbent tends to innovate with a higher probability than the entrant. Secondly we find excess absorptive capacity to increase (decrease) the incumbent's (entrant's) equilibrium payoffs.

Our paper suggests a number of extensions. First some of our (main) conclusions hinge on the fact that innovation efforts are strategic substitutes. If one defines innovation efforts as a flow of investments rather than an up-front expenditure, however, the firms strategic variables are (often) complements[13] and it remains to be validated in how far our results sustain in these cases[14]. Closely related, secondly, we applied a static set-up for something dynamic in nature. For a dynamic R&D race with knowledge accumulation Doraszelski (2003) derives simulation results that suggest firms invest more aggressively if they have a large knowledge stock. This bears resemblance to our aggressive innovation finding but seems to jar with the outcome of the copycat strategy. It appears worthwhile to integrating the advantages of both set-ups, an explicit formulation of absorptive capacity and the multistage nature of the Doraszelski (2003) model. Thirdly Hoppe et al. (2005) identify free-riding effects among several incumbents who bid for a license in order to prevent entrants to obtain the license. Similar to their context in which each incumbent is willing to avoid entry but would rather prefer the other incumbent to pay the price of preemption, in our model several incumbents might rely on each other to bear the costs of maintaining an excess absorptive capacity.

[13] See Martin 1999 for an overview of R&D games with strategic substitutes and complements.

[14] Chen (2000) shows that an incumbent's and an entrant's innovation investments depend crucially on whether the new product is a strategic substitute or complement to the monopolists old product.

Proof of Lemma 1. For notational convenience let $f_I = 0$ and $f_E = 0$ denote the incumbent's and the entrant's first-order-conditions as given by (3) and (4) respectively. Note that $\partial f_i/\partial\alpha_i = -a < 0$, $i = I, E$ and the Hessian determinant

$$\begin{aligned}\begin{vmatrix} \partial f_I/\partial\alpha_I & \partial f_I/\partial\alpha_E \\ \partial f_E/\partial\alpha_I & \partial f_E/\partial\alpha_E \end{vmatrix} &= (\partial f_I/\partial\alpha_I)(\partial f_E/\partial\alpha_E) - (\partial f_I/\partial\alpha_E)(\partial f_E/\partial\alpha_I) \\ &= a^2 - \Omega(1-\beta_I)(\pi^L - \pi^D) > 0, \qquad (18)\end{aligned}$$

where

$$\Omega = (\pi^M(\underline{c}) - \pi^M(\overline{c})) - (1-\beta_I)(\pi^D - \pi^F), \qquad (19)$$

$0 < \Omega < a$. This establishes uniqueness and stability (first claim).

Letting α_I^* and α_E^* denote the Nash equilibrium as implied by $f_I = 0$ and $f_E = 0$, we have by the implictit function rule and Cramer's rule that

$$\frac{\partial\alpha_i^*}{\partial\Pi} = \frac{|J_i^\Pi|}{|J|}, \quad i = I, E, \quad \Pi = \pi^M(\underline{c}), \pi^M(\overline{c}), \pi^L, \pi^D, \pi^F,$$

where $|J|$ is the Jacobian determinant of the equation system $f_I = 0$ and $f_E = 0$, which is here of course given by (18), and $|J_i^\Pi|$ is the determinant of the Jacobian with the i'th column replaced with partial derivatives, $-\partial f_i/\partial\Pi$. In particular

$$\left|J_I^{\pi^M(\underline{c})}\right| = \begin{vmatrix} -\partial f_I/\partial\pi^M(\underline{c}) & \partial f_I/\partial\alpha_E \\ -\partial f_E/\partial\pi^M(\underline{c}) & \partial f_E/\partial\alpha_E \end{vmatrix} = a(1-\alpha_E^*) > 0,$$

which implies, as $|J| > 0$ by (18), that $\partial\alpha_i^*/\partial\pi^M(\underline{c}) > 0$. Respectively we obtain

$$\begin{aligned}\left|J_I^{\pi^M(\overline{c})}\right| &= -a(1-\alpha_E^*) \Rightarrow \partial\alpha_I^*/\partial\pi^M(\overline{c}) < 0 \\ \left|J_I^{\pi^L}\right| &= -(1-\alpha_I^*)(1-\beta_I)\Omega \Rightarrow \partial\alpha_I^*/\partial\pi^L < 0 \\ \left|J_I^{\pi^D}\right| &= -a\alpha_E^*(\pi^D - \pi^F) - (\alpha_I^*(1-\beta_I) + \beta_I)\Omega \Rightarrow \partial\alpha_I^*/\partial\pi^D < 0 \\ \left|J_I^{\pi^F}\right| &= -a(1-\beta_I)\alpha_E^* \Rightarrow \partial\alpha_I^*/\partial\pi^F < 0.\end{aligned}$$

This establishes part *(a)*.

Next we calculate

$$
\begin{aligned}
\left|J_E^{\pi^M(\underline{c})}\right| &= \begin{vmatrix} \partial f_I/\partial\alpha_I & -\partial f_I/\partial\pi^M(\underline{c}) \\ \partial f_E/\partial\alpha_I & -\partial f_E/\partial\pi^M(\underline{c}) \end{vmatrix} \\
&= -(1-a_E^*)(1-\beta_I)(\pi^L-\pi^D) \Rightarrow \partial\alpha_E^*/\partial\pi^M(\underline{c}) < 0.
\end{aligned}
$$

Proceeding in a similar fashion yields

$$
\begin{aligned}
\left|J_E^{\pi^M(\overline{c})}\right| &= (1-a_E^*)(1-\beta_I)(\pi^L-\pi^D) \Rightarrow \partial\alpha_E^*/\partial\pi^M(\overline{c}) > 0, \\
\left|J_E^{\pi^L}\right| &= a(1-\alpha_I^*)(1-\beta_I) \Rightarrow \partial\alpha_E^*/\partial\pi^L > 0, \\
\left|J_E^{\pi^D}\right| &= a(\alpha_I^*(1-\beta_I)+\beta_I)+\alpha_E^*(1-\beta_I)(\pi^D-\pi^F)(\pi^L-\pi^D) \\
&\Rightarrow \partial\alpha_E^*/\partial\pi^D > 0, \\
\left|J_E^{\pi^F}\right| &= (-1+\beta_I)^2\alpha_E^*(\pi^L-\pi^D) \Rightarrow \partial\alpha_E^*/\partial\pi^F > 0
\end{aligned}
$$

This establishes part *(b)*.■

Proof of Proposition 3. Unfortunately implicit differentiation as in the proof of Lemma 1 does not reveal the sign of $\partial\alpha_I^*/\partial\beta_I$ and $\partial\alpha_E^*/\partial\beta_I$ respectively (see Proof of Proposition 4). Therefore we solve the first-order-conditions (3) and (4) simultaneously for

$$
\alpha_I^* = \frac{a(\pi^M(\underline{c})-\pi^M(\overline{c}))-\Omega(\pi^L-\beta_I(\pi^L-\pi^D))}{a^2-\Omega(1-\beta_I)(\pi^L-\pi^D)} \tag{20}
$$

and

$$
\alpha_E^* = \frac{a(\pi^L-\beta_I(\pi^L-\pi^D))-(1-\beta_I)(\pi^M(\underline{c})-\pi^M(\overline{c}))(\pi^L-\pi^D)}{a^2-\Omega(1-\beta_I)(\pi^L-\pi^D)}, \tag{21}
$$

where Ω is given by (19).

First claim. Letting N_I and D denote the numerator and the denominator of (20), we can write

$$
\frac{\partial\alpha_I^*}{\partial\beta_I} = \frac{(\partial N_I/\partial\beta_I)D-(\partial D/\partial\beta_I)N_I}{D^2},
$$

where

$$
\frac{\partial N_I}{\partial\beta_I} = (\pi^M(\underline{c})-\pi^M(\overline{c}))(\pi^L-\pi^D)-(\pi^D-\pi^F)\left[2\pi^L(1-\beta_I)-\pi^D(1-2\beta_I)\right],
$$

and
$$\frac{\partial D}{\partial \beta_I} = \left[(\pi^M(\underline{c}) - \pi^M(\overline{c})) - 2(1-\beta_I)(\pi^D - \pi^F)\right](\pi^L - \pi^D).$$

Note that

$$\begin{aligned}
& \partial N_I/\partial\beta_I - \partial D/\partial\beta_I \\
= \; & (\pi^D - \pi^F)\left\{2(1-\beta_I)(\pi^L - \pi^D) - [2\pi_L(1-\beta_I) - \pi_D(1-2\beta_I)]\right\} \\
= \; & -(\pi^D - \pi^F)\pi^D
\end{aligned}$$

and hence $\partial N_I/\partial\beta_I < \partial D/\partial\beta_I$. Now suppose that $\partial N_I/\partial\beta_I \leqslant 0$. On the one hand, if $\partial D/\partial\beta_I > 0$ then $\partial\alpha_I^*/\partial\beta_I$ is unambiguously negative, because $D > 0 \wedge N > 0$. On the other hand, if $\partial D/\partial\beta_I < 0$ then $\partial\alpha_I^*/\partial\beta_I < 0$ because $\partial D/\partial\beta_I < 0 \Longrightarrow |\partial N_I/\partial\beta_I| > |\partial D/\partial\beta_I|$ and $D \geqslant N$. It is the case that $\partial N_I/\partial\beta_I \leqslant 0$ if and only if

$$\frac{\pi^M(\underline{c}) - \pi^M(\overline{c})}{\pi^D - \pi^F} \leqslant \frac{\left[2\pi^L(1-\beta_I) - \pi^D(1-2\beta_I)\right]}{\pi^L - \pi^D}$$

which can be re-written as

$$\begin{aligned}
\frac{\pi^M(\underline{c}) - \pi^M(\overline{c})}{\pi^D - \pi^F} \quad & \leqslant \quad \frac{\pi^L + (\pi^L - \pi^D)(1-2\beta_I)}{\pi^L - \pi^D} \\
\Longleftrightarrow \frac{\pi^M(\underline{c}) - \pi^M(\overline{c})}{\pi^D - \pi^F} + 2\beta_I \quad & \leqslant \quad \frac{\pi^L}{\pi^L - \pi^D} + 1.
\end{aligned}$$

This establishes the first claim.

Second claim.
$$\frac{\partial\alpha_E^*}{\partial\beta_I} = -\frac{1}{D^2}(\pi^L - \pi^D)\Phi,$$

where

$$\begin{aligned}
& \Phi = a^3 - a^2(\pi^M(\underline{c}) - \pi^M(\overline{c})) \\
& +(-1+\beta_I)^2(\pi^M(\underline{c}) - \pi^M(\overline{c}))(\pi^L - \pi^D)(\pi^D - \pi^F) \\
& +a((\pi^M(\underline{c}) - \pi^M(\overline{c}))\pi^D - (1-\beta_I)(\pi^D - \pi^F)(\pi^D(1+\beta_I) + \pi^L(1-\beta_I)).
\end{aligned}$$

Note that $\partial\alpha_E^*/\partial\beta_I$ is negative as long as Φ is positive. We have that

$$\frac{\partial\Phi}{\partial\pi^M(\underline{c})} = -a(a - \pi^D) + (-1+\beta_I)^2(\pi^L - \pi^D)(\pi^D - \pi^F) < 0$$

because $a > (\pi^D - \pi^F) \wedge (a - \pi^D) > (\pi^L - \pi^D)$ and respectively

$$\frac{\partial \Phi}{\partial \pi^M(\overline{c})} = a(a - \pi^D) - (-1 + \beta_I)^2(\pi^L - \pi^D)(\pi^D - \pi^F) > 0.$$

We set $\pi^M(\underline{c}) = a$ and $\partial \pi^M(\overline{c}) = 0$ in order to evaluate Φ below its minimum level:

$$\Phi \left|_{\pi^M(\underline{c})=a,\ \pi^M(\overline{c})=0} \right. = a\pi^D(a - 2(1 - \beta_I)(\pi^D - \pi^F)) > 0,$$

because, by the efficiency effect, $a > \pi^M(\underline{c}) > 2\pi^D$. (Second claim).■

Proof of Proposition 4. By similar arguments as in the proof of Lemma 1 we derive

$$\begin{aligned} \left|J_I^{\beta_I}\right| &= (1 - \alpha_I^*)(\pi^L - \pi^D)\Omega - a\alpha_E^*(\pi^D - \pi^F) \\ \left|J_E^{\beta_I}\right| &= (\alpha_E^*(1 - \beta_I)(\pi^D - \pi^F) - a(1 - \alpha_I^*)(\pi^L - \pi^D), \end{aligned}$$

to establish, after some re-arrengements, that

$$\begin{aligned} \left|J_I^{\beta_I}\right| + \left|J_E^{\beta_I}\right| &= -\alpha_E^*(\pi^D - \pi^F)(a - (1 - \beta_I)(\pi^L - \pi^D) \\ &\quad -(1 - \alpha_I^*)(\pi^L - \pi^D)(a - \Omega) \\ &\Rightarrow \partial\alpha_I^*/\partial\beta_I + \partial\alpha_E^*/\partial\beta_I < 0. \end{aligned}$$

■

Proof of Proposition 5. First claim. Letting N_I and N_E still denote the numerators of (20) and (21) we have that $sign(\alpha_I^* - \alpha_E^*) \Longleftrightarrow sign(N_I - N_E)$. After some re-arrangements we can write

$$\begin{aligned} &N_I - N_E = a\left\{(\pi^M(\underline{c}) - \pi^M(\overline{c})) - (\pi^L - \beta_I(\pi^L - \pi^D))\right\} \\ &- \left\{(1 - \beta_I)(\pi^L - \pi^D)(\pi^M(\underline{c}) - \pi^M(\overline{c})) + \Omega(\pi^L - \beta_I(\pi^L - \pi^D))\right\}, \end{aligned}$$

where the first curely bracketed term is negative if and only if

$$\beta_I < \frac{\pi^L - (\pi^M(\underline{c}) - \pi^M(\overline{c}))}{\pi^L - \pi^D},$$

and the second curely bracketed term is strictly positive. This establishes the first claim.

The second claim follows by

$$\frac{\partial(N_I - N_E)}{\partial\beta_I} = -a(\pi^L - \pi^D) - (\pi^D - \pi^F)(2\pi^L(1-\beta_I) - \pi^D(1-2\beta_I)) < 0,$$

and the third claim follows straightforwardly upon setting $\beta_I = 1$ in (21).■

Proof of Proposition 6. First claim (entry accomodation). Straightforward by (15).

Second claim (entry deterrence). By (17) $dV_E/d\beta_I < 0$ if $\partial\alpha_I^*/\partial\beta_I > 0$. If $\partial\alpha_I^*/\partial\beta_I < 0$ then $dV_E/d\beta_I < 0$ if and only if

$$\begin{aligned}
1 - \alpha_I^* &> (1-\beta_I)(\partial\alpha_I^*/\partial\beta_I) \\
1 &> (1-\beta_I)\frac{(\partial N_I/\partial\beta_I)D - (\partial D/\partial\beta_I)N_I}{D^2} + \frac{N_I * D}{D^2} \\
0 &> (1-\beta_I)((\partial N_I/\partial\beta_I)D - (\partial D/\partial\beta_I)N_I) + N_I * D - D^2
\end{aligned}$$

[to be completed]

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