THE EFFECT OF EXIT ON ENTRY DETERRENCE STRATEGIES

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ABSTRACT

Recent analyses of entry deterrence strategies have required an incumbent's post-entry output or pricing strategy to be profit maximizing. However, most papers have continued to assume that either an incumbent can commit not to exit after entry or that exit is never optimal. When there are avoidable fixed costs of operating in any period, however, exit can be the optimal strategy. In this situation, entry deterrence strategies operate very differently than when exit is never optimal. In fact, the possibility of exit can make some, previously effective, strategies completely ineffective while improving the effectiveness of others.

"Because technology such as software requires huge fixed investment up-front, but involves trivial marginal costs, it is highly likely that competition will result in 'fragile monopolies' being created, with single companies dominating segments for a time, until they are toppled by rivals." *The Economist*, "The New Enforcers." October 7, 2000.

I. INTRODUCTION

With the advent of game theory, economists recognized that entry deterrence strategies must be credible. Imposing this credibility requirement in a price or quantity setting game with the entrant has had a profound effect on the analysis of entry deterrence strategies such as capacity expansion (e.g., Dixit 1980 and Bulow et. al. 1985). This literature has focused on the case where exit by the incumbent following entry is never optimal. In this paper, I analyze the alternative situation where the incumbent may find it ex post optimal to exit following entry and cannot credibly commit to remain in the market. While it is well known that the possibility of exit weakens an incumbent's ability to deter entry (Bagwell and Ramey 1996), the literature has yet to analyze how the possibility of exit affects different types of entry deterrence strategies. I show that this effect can be quite profound. In particular, decreasing an entrant's duopoly profits often will not deter entry, but increasing the incumbent's post-entry profitability often will.

In industries with large fixed, but not sunk, costs, exit may be the incumbent's profit maximizing strategy when facing an entrant that is much more efficient or has a far superior product. American Airlines decided to abandon its San Jose hub and many routes within California shortly after Southwest Airlines entered the San Jose market because it worried it might not be able to compete with Southwest's low fares (San Jose Mercury News 1993; Washington Post 1993). In fact, as the above quote indicates, exit by dominant firms could become increasingly common in many industries as rapidly advancing technology provides opportunities for entrants to develop products that are greatly superior to those offered by incumbents. Thus, it is more important than ever to expand the analysis of entry deterrence strategies to cover the case where the incumbent might exit.

To show how entry-deterring strategies can affect the credibility of the incumbent's no exit threat, I consider a model where the entrant's ability to compete is private information. The crucial insight is similar to Nalebuff's (1987) insight about the effect of credibility in pretrial settlement negotiations. The more the incumbent invests in decreasing the profitability of entry, the more efficient is the entrant it is likely to face given that entry occurs. This reduces the credibility of the incumbent's threat not to exit. As a result, in some circumstances, increases in entry costs have *no* effect on the probability of entry because they do not affect the incumbent's incentive to exit. Strategies such as lobbying for tighter environmental standards for new plants, signing exclusive contracts with suppliers, or buying up critical resources that are in limited supply will *not* be effective in deterring entry when exit is possible (but not certain). This is even true for regulations that raise the marginal costs of a new entrant, thus reducing its expected profit from entry, so long as they also raise the incumbent's marginal cost enough to reduce its profitability after entry. As surprising as this seems, it follows because the less profitable entry is, the more effective a competitor an entrant must be to warrant entry. This reduces the expected profits of the incumbent, making it more likely to exit. This increase in the exit probability induces more entry, counteracting the decreased profitability of entry. On the other hand, advertising that expands the market for both the incumbent and the entrant can actually *deter* entry in these circumstances because it increases the incumbent's expected profits if entry occurs.[1]

While most of the literature on entry deterrence has focused on the case where exit by the incumbent is never optimal, there are a few exceptions. Judd (1985) shows that the inability to commit not to exit limits an incumbent's ability to deter entry into a nearby market by preemptively entering that market first. Eaton and Lipsey (1980) allow for exit to discuss optimal durability and replacement of sunk capital. Neither of these papers, however, considers the impact of exit on the type of entry

[1] One can imagine some types of demand curves (such as constant elasticity demand) where a parallel shift out of the demand curve might actually reduce duopoly profits by inducing each firm to compete more aggressively. In these unusual circumstances, advertising that shifted the demand curve out would not deter entry since it would not increase the incumbent's duopoly profits. I thank Jeremy Bulow for pointing this out.

deterrence strategies discussed here.[2] Moreover, both use complete information models, so they don't consider the interaction of asymmetric information and exit, the essence of this paper.

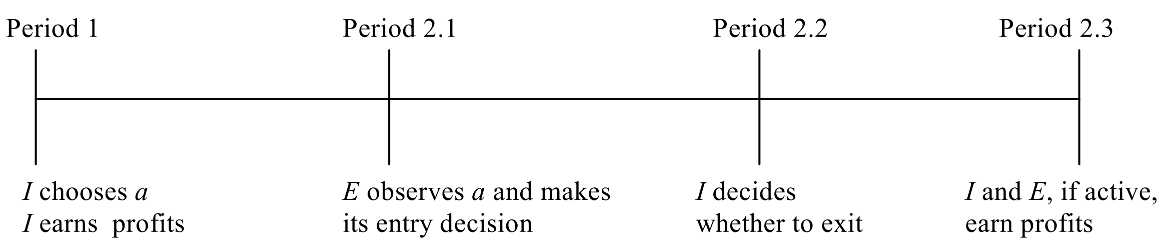
In the investment in entry deterrence literature, both Arvan (1986) and Bagwell and Ramey (1996) (in capacity models) allow for the possibility of exit by the incumbent following entry. In Arvan's paper, however, because the uncertainty is about the incumbent's technology, not the entrant's, there is no interaction between the entry deterring strategy and the exit decision. In Bagwell and Ramey, there is no asymmetric information; they link capacity expansion and exit via forward induction. Due to forward induction, the incumbent assumes that the entrant will produce a large enough quantity to cover its entry costs assuming the incumbent takes this output level as given. As a result, the incumbent wants to constrain its capacity so that the entrant can enter and make positive profit without the incumbent exiting. Like their paper, I show that exit can make entry deterrence strategies less effective. My paper, however, obtains this result with asymmetric information rather than forward induction. This distinction is fundamental because it is both the possibility of exit and uncertainty about the entrant's type that generate the result that, in some cases, entry can only be deterred by decreasing the incentive to exit, not by decreasing the profitability of entry.

The plan of the paper is as follows. Section II outlines the model. Section III describes the equilibrium of the entry and exit subgame. Section IV works through a Cournot example that illustrates effects of the mixed strategy equilibrium. Section V analyzes the mixed exit strategy equilibrium in a more general framework. Sub-section V.1 analyzes entry deterrence in this equilibrium and compares it to the no exit benchmark case. Sub-section V.2 discusses some robustness issues. Section VI concludes. The Appendix contains proofs omitted from the text.

[2] The spatial preemption model of Judd (1985) could be seen as a special case of the strategies I discuss below. However, since there is no uncertainty in his model and the entry deterrence strategy is of fixed magnitude, the equilibrium result is exit with probability one. Therefore, the most interesting equilibrium, the mixed strategy equilibrium, does not arise in Judd's model. By the same token, since this paper does not consider spatial markets, it does not cover the interesting aspects of Judd's model. Thus, while his paper has similarities with this one, both the situations it covers and its results are quite distinct.

II. THE MODEL

Consider a two period model where production in any period requires the expenditure of fixed costs in that period (negative profits are possible). In period 1, only the incumbent, *I*, is in the market. Its costs are common knowledge. There is a potential entrant, *E*, that can enter in period 2. Its marginal cost parameter, *c*, is private information (note, this does not imply that the entrant's marginal costs are constant, only that its marginal costs are a function only of its output and *c*). The incumbent knows only that *c* is distributed according to the (differentiable) cumulative distribution function *G*, with density function *g*, and support $[\underline{c},\bar{c}]$.[3] In period 1, *I* chooses some (observable) costly action, $a \in A$, that affects either the entrant's or incumbent's net profits (or both) in period 2. Period 2 is divided into three stages. In 2.1, *E* decides whether to enter the market. In 2.2, *I*, having observed the entry decision (but not *E*'s cost parameter), decides whether or not to exit. In period 2.3, *I* and *E* (if in the market) earn profits. When analyzing the special case of Cournot competition in period 2.3 (section IV and Proposition 2), I assume for simplicity that *I* observes *c* prior to choosing its quantity in period 2.3. I do *not* make this assumption when analyzing the general game, nor does the main result of the paper, Proposition 1, depend on this assumption.[4] I employ the Perfect Bayesian Equilibrium concept for this game.



I's first period monopoly profits are given by $\pi_{I1}(a)$. This includes its fixed operating cost. I

[3] *c* could also be interpreted as a parameter measuring the quality of the entrant's good rather than its production cost. In this interpretation, higher *c* should be thought of as lower quality.

[4] One can also generalize the proof of Proposition 2 so that it applies to the case where the entrant's costs remain unobservable when the incumbent chooses its quantity in the Cournot game. This proof is available from the author upon request.

assume $\pi_{I1}(a)$ is decreasing and strictly concave in *a*: *a* is an action that has immediate costs but no immediate benefits (such as an investment in future cost reduction, advertising that expands the market in the future, or raising entry costs). Thus, the myopically optimal *a* is zero. If *I* exits, it earns zero profits in period 2.3. If *I* does not exit, then in 2.3 it earns duopoly profits of $\pi_{I2d}(a,c)$ if *E* entered in 2.1 and monopoly profits of $\pi_{I2m}(a)$ if *E* did not enter (both net of fixed costs). $\pi_{I2d}(a,c)$ is increasing in *c* (if the entrant's costs are higher, then the incumbent's duopoly profits are higher) and both $\pi_{I2d}(a,c)$ and $\pi_{I2m}(a)$ are weakly increasing in *a* (this will be strict for some types of *a*, for example if *a* is investment in cost reduction or advertising), and $\pi_{I2m}(a) > \pi_{I2d}(a,c), \forall c$. If *E* enters in period 2.1 and *I* does not (does) exit in 2.2, then *E*'s duopoly (monopoly) profits are given by $\pi_{E2d}(a,c)$ ($\pi_{E2m}(a,c)$), inclusive of entry costs; $\pi_{E2m}(a,c) > \pi_{E2d}(a,c)$. Both are decreasing in *c* and monotonic in *a*. The entrant's profits can be monotonically decreasing in *a*, e.g., when *a* represents the incumbent's investment in cost reduction or capacity expansion (and *I* does not exit) or when *a* is an investment in increasing entry costs. The entrant's profits can also be monotonically increasing in *a*, e.g., when *a* is advertising that expands the market. All profit functions are twice continuously differentiable in both *c* and *a*.

At this point, and in most of the paper except where specified otherwise, the profit functions for each player in a given period are reduced form profit functions. That is, I do not explicitly model how each player chooses its control variables that only affect current period profits (such as price or quantity). For example, consider $\pi_{I2d}(a,c)$. Whenever this general form is used, I make no assumptions about whether period 2.3 competition is, for example, Cournot or Bertrand (or perfect collusion), or about whether *E*'s cost parameter remains private information or becomes common knowledge before the incumbent chooses its control variables. Any of these assumptions is permissible so long as $\pi_{I2d}(a,c)$ satisfies the properties assumed above. If this is the case, the particulars of the period 2.3 game do not affect the main result of the paper (Proposition 1).

Notice that, while I have allowed the incumbent to save avoidable fixed costs by exiting the market after observing the entry decision, I do not allow the entrant to exit, and save its entry costs, after observing the incumbent's exit decision. This is critical, otherwise *I* could effectively commit not to exit because if *E* could back out of its entry decision at zero cost, the initial entry decision would be meaningless, making *I* a first mover.[5]

III. PERIOD 2 EQUILIBRIUM

Because the entrant's costs are private information, the incumbent's response to entry cannot be conditioned on the entrant's type. Since the incumbent observes the entry decision, however, its exit decision will depend on its beliefs about the entrant's type given the entry decision. Similarly, since the entrant must enter before observing the incumbent's exit decision, its entry decision will depend on its beliefs about the probability of exit. A period 2 equilibrium occurs when both the incumbent's and entrant's beliefs are correct and the entry and exit decisions are best responses to those beliefs about the other's strategy.

If the incumbent exits with probability *p(a)*, then the entrant's profits from entry are:

$$\pi_E(a,c) = (1-p(a))\pi_{E2d}(a,c) + p(a)\pi_{E2m}(a,c) \tag{1}$$

Equation (1) implies that there is a cutoff level for *E*'s cost parameter, $\hat{c}(a)$, such that *E* enters if and only if $c < \hat{c}(a)$ (if its costs are low enough, *E* can earn positive expected profits from entry). Of course, the entrant does not observe *p(a)* when making its entry decision, although the entrant will correctly predict this exit probability in equilibrium. Thus, *p(a)* in (1) (and (2) below) should be thought of as the entrant's conjecture of the incumbent's exit probability. This cutoff, $\hat{c}(a)$, is defined implicitly by:

$$(1-p(a))\pi_{E2d}(a,\hat{c}(a)) + p(a)\pi_{E2m}(a,\hat{c}(a)) = 0 \tag{2}$$

It will not necessarily be the case that $\hat{c}(a) \in [\underline{c}, \bar{c}]$. If the $\hat{c}(a)$ that solves (2) is less than $\underline{c}$, then the entrant's costs will never be low enough to enter. On the other hand, if the $\hat{c}(a)$ that solves (2) is

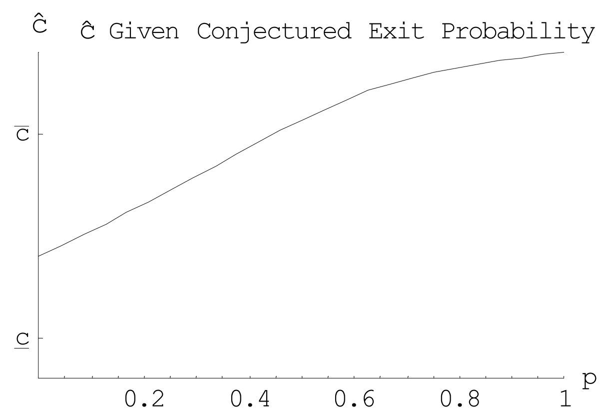
[5] If, after the entrant sunk an entry cost in 2.1, the entrant and incumbent both had avoidable fixed costs and played a simultaneous move exit game in 2.2, the equilibrium in Section III remains an equilibrium of this modified game, though it is no longer the unique equilibrium.

greater than $\bar{c}$, then the entrant's costs will always be low enough that entry is profitable. I further define $c^d(a)$ and $c^m(a)$ implicitly as follows:

$$\pi_{E2d}(a, c^d(a)) = 0 \text{ and } \pi_{E2m}(a, c^m(a)) = 0 \tag{3}$$

That is, $c^d(a)$ is the entrant's cost cutoff level if the incumbent does not exit (*p(a)=0*) and $c^m(a)$ is the cutoff level when the incumbent always exits (*p(a)=1*). It follows from (2) that $\hat{c}(a)$ is increasing in *p(a)*, *E*'s (correct) conjecture of the probability that *I* exits, and $c^d(a) \le \hat{c}(a) \le c^m(a)$. This relationship is depicted in the following figure.[6]

Figure 1



In this figure, the entrant will always enter if it believes the probability of exit is fairly high ($\bar{c} < \hat{c}(a)$ when *p* is large), and the entrant enters with positive probability even if it believes the incumbent will never exit ($\underline{c} < \hat{c}(a)$ even when *p=0*). As Figure 3, below, shows, neither of these will hold in general. What is generally true, as one can see from (2), is that the optimal entry cutoff is increasing in the entrant's conjecture of the probability of exit.

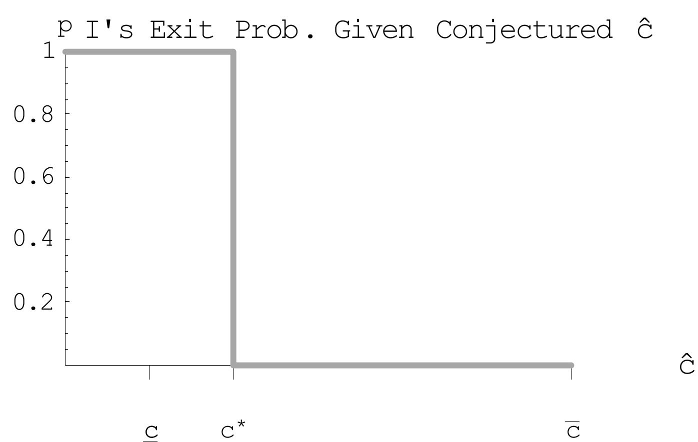
[6] The exact curves in Figures 1, 2, and 3 are derived based on Cournot competition in period 2.3, constant marginal costs (which are common knowledge in period 2.3), linear demand, and a uniform distribution for the entrant's marginal costs. The qualitative results from the figures, however, do not depend on these specifications.

For any given conjecture about the entrant's entry strategy, enter if $c < \hat{c}(a)$, the incumbent will exit with probability zero (one) whenever its expected second period duopoly profits are positive (negative). If second period expected duopoly profits are zero, incumbent can play a mixed exit strategy. Thus, the incumbent's exit strategy is determined by the sign of the following:

$$\int_{\underline{c}}^{\hat{c}(a)} \pi_{I2d}(a,c)g(c)dc \tag{4}$$

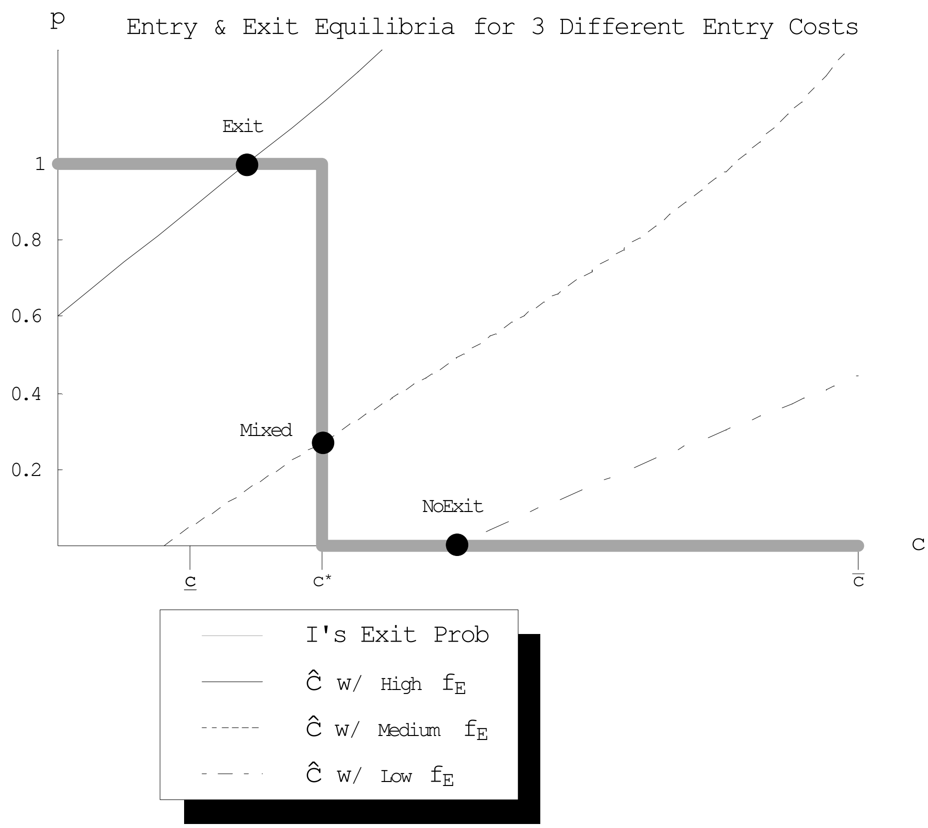
Again, since the incumbent does not observe the entry strategy, $\hat{c}(a)$ in (4) is the incumbent's conjecture (correct in equilibrium) of the entrant's actual entry cutoff. Figure 2 depicts the incumbent's exit probability as a function of this conjecture of $\hat{c}(a)$. The point $c*(a)$ is the entry strategy that makes the incumbent indifferent between exiting and not, defined implicitly by $\int_{\underline{c}}^{c*(a)} \pi_{I2d}(a,c)g(c)dc = 0$.

Figure 2



Combining these two plots on the same graph demonstrates that there is a unique equilibrium to the period 2 entry and exit subgame in which the entrant's beliefs about the incumbent's exit probability and the incumbent's beliefs about the entrant's entry strategy are correct. Figure 3 depicts three possible equilibria (the black dots) for three different entrant profit functions (that differ in entry costs), each of which generates a different curve depicting the entrant's choice of $\hat{c}$ as a function of *p*.

Figure 3



When entry costs are large (the solid line), the entrant must have small marginal costs to enter for any given probability of exit. The period 2 equilibrium has exit with probability one (conditional on entry) because when the incumbent observes entry it knows it will make negative expected profits competing with a low marginal cost entrant. This equilibrium occurs whenever $a \in A^X$, where A^X is defined as follows:

$$A^X = \{a \in A : \int_{\underline{c}}^{c^m(a)} \pi_{I2d}(a,c)g(c)dc \leq 0\} = \{a \in A : c^m(a) \leq c^*(a)\}$$

That is, A^X is the set of actions that generate a second period market that is so difficult for an entrant that in order for an entrant to make positive monopoly profits its marginal costs must be so small that the incumbent cannot make positive expected profits competing against this entrant.

When entry costs are very small (the dashed line), an entrant with high marginal costs can make positive duopoly profits. Given this, both the incumbent and entrant can simultaneously have positive expected duopoly profits; the period 2 equilibrium has exit with probability zero. This equilibrium occurs when $a \in A^N$, where A^N is the following set:

$$A^N = \{a \in A : \int_{\underline{c}}^{c^d(a)} \pi_{I2d}(a,c)g(c)dc \geq 0\} = \{a \in A : c^d(a) \geq c^*(a)\}$$

That is, A^N is the set of actions that generate a second period market that is profitable enough for an entrant that it can make positive duopoly profits with marginal costs that are high enough the incumbent can make positive expected profits competing against this entrant.

For intermediate entry costs (depicted by the dotted line in the figure), the break-even cost curve intersects the exit probability curve exactly at the point where the incumbent earns zero expected profits given entry. This mixed strategy equilibrium occurs when $a \in A^M$ and A^M is given by:

$$A^M = \{a \in A : \int_{\underline{c}}^{c^d(a)} \pi_{I2d}(a,c)g(c)dc < 0, \int_{\underline{c}}^{c^m(a)} \pi_{I2d}(a,c)g(c)dc > 0\} = \{a \in A : c^d(a) < c^*(a) < c^m(a)\}$$

That is, A^M is the set of actions that generate a second period market that is not so profitable that the incumbent can make positive expected profits competing against an entrant that can make positive duopoly profits; but it is profitable enough that the incumbent can make positive expected profits competing against an entrant that makes positive monopoly profits.

One might wonder whether the sets that define the type of entry and exit equilibrium that occurs for any given *a* are connected (that is, are they each one interval)? If the effect of *a* on *I*'s and *E*'s profits is in the same direction, then $\int_{\underline{c}}^{c^j(a)} \pi_{I2d}(a,c)g(c)dc$ is monotonic in *a* (*j=d,m*). This ensures that each of the above sets is connected. This covers all the examples I have discussed except for marginal cost reduction. In that case, *a* increases *I*'s duopoly profits and decreases *E*'s duopoly profits. Thus, it is possible that A^N and/or A^M is not connected (A^X will remain connected since *a* does not affect *E*'s monopoly profits). If increasing investment in cost reduction at some levels reduces $c^d(a)$ so much that it actually reduces the incumbent's expected profits given entry, while at other levels the reverse is true, then either A^N or A^M could consist of multiple intervals. This, however, does not affect any of the analysis that follows.

Of course, there is no guarantee that all of these sets are non-empty for all possible parameter values. For example, if the market is large relative to entry costs, then the incumbent might be in the no exit set for all *a*. On the other hand, if duopoly competition takes the Bertrand form and $c^m(a)$ is less than the incumbent's marginal cost, then the incumbent will always exit whenever there is entry. If both A^X and A^N are non-empty, however, then A^M must be non-empty also. This follows from the fact that $c^d(a) < c^m(a)$ and $\pi_{I2d}(a,c)$ is increasing in c.

Given the equilibrium in this subgame, the incumbent's inter-temporal profit function is:

$$\Pi_I(a) = \pi_{I1}(a) + \beta\{(1-p(a))\int_{\underline{c}}^{\hat{c}(a)}(\pi_{I2d}(a,c))g(c)dc + (1-G(\hat{c}(a)))(\pi_{I2m}(a))\} \tag{5}$$

In period 1, *I* is a monopolist, earning $\pi_{I1}(a)$. Second period profits are discounted by β. If *I* exits, then *I* earns zero. If, when *E* enters, i.e., when $c \in [\underline{c}, \hat{c}(a))$, *I* does not exit (this happens with probability $(1-p(a))$), then *I* earns duopoly profits of $\pi_{I2d}(a,c)$. If *E*'s does not enter, *I* earns monopoly profits in period 2.

IV. A COURNOT EXAMPLE

Before proceeding to a general analysis of the effects of the mixed exit strategy equilibrium, I will illustrate the main results using a simple linear demand, Cournot example. Section V shows that these results hold more generally. Say demand in each period is given by $q = z - p$, the incumbent has constant marginal cost of c_I and c, the entrant's marginal cost, is uniformly distributed between *0* and *1*. Further, to make determining the equilibrium quantities simpler, assume that prior to period 2.3, the incumbent learns the entrant's marginal cost. Then, in 2.3 firm *j=I,E* (where c_E=*c*) chooses q_j to maximize:

$$q_j(z-(q_j+q_{-j})-c_j) \tag{6}$$

The first order condition for q_j is:

$$z - (2q_j + q_{-j}) - c_j = 0 \tag{7}$$

The Cournot-Nash equilibrium quantities are:

$$q_j = \frac{z - 2c_j + c_{-j}}{3} \tag{8}$$

The reduced form duopoly profit functions (for $j=I,E$) are (where f_j is firm j's fixed cost):

$$\pi_{j2d} = \frac{(z - 2c_j + c_{-j})^2}{9} - f_j \tag{9}$$

Similarly, the reduced form monopoly profit functions are:

$$\pi_{j2m} = \frac{(z - c_j)^2}{4} - f_j \tag{10}$$

If the entrant expects the incumbent to exit with probability zero, then it will enter whenever $\pi_{E2d} \geq 0$.

From (9), this means the entrant enters if and only if:

$$c < c^d = (1/2)(z + c_I - 3\sqrt{f_E}) \tag{11}$$

If the entrant expects the incumbent to exit with probability one, then it will enter whenever $\pi_{E2m} \geq 0$.

From (10), this means the entrant enters if and only if:

$$c < c^m = (z - 2\sqrt{f_E}) \tag{12}$$

The incumbent's exit decision is depends on whether or not its expected duopoly profits are positive.

Using (9), the incumbent exits, given entry, with probability one (zero) if an only if:

$$\int_0^{\hat{c}} \left(\frac{(z - 2c_I + c)^2}{9} - f_I\right) dc < (>) 0 \quad \text{or} \tag{13}$$

$$\hat{c} < (>)\, c^* = (1/2)[6c_I - 3z - \sqrt{3(36 f_I - (z - 2c_I)^2)}] \tag{14}$$

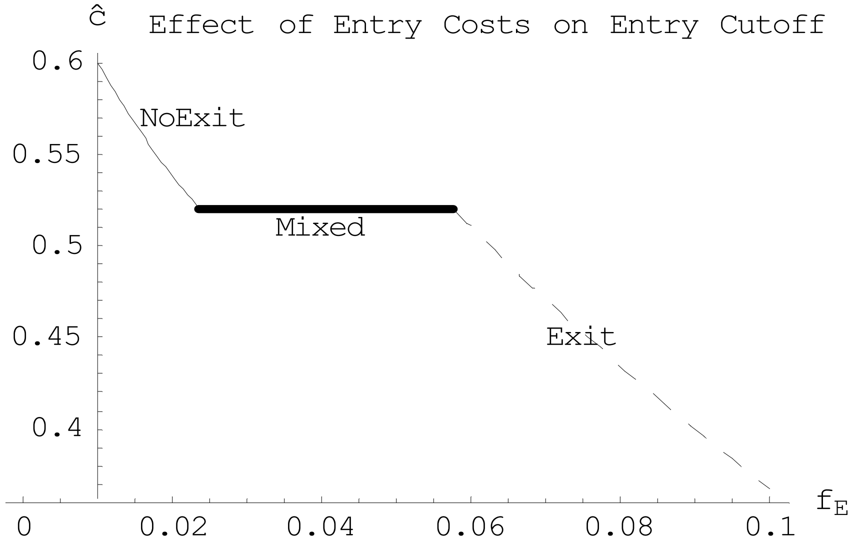
Of course, the incumbent plays a mixed exit strategy if and only if $\hat{c} = c^*$. A mixed exit strategy equilibrium must occur if and only if:

$$(1/2)(z + c_I - 3\sqrt{f_E}) < (1/2)[6c_I - 3z - \sqrt{3(36 f_I - (z - 2c_I)^2)}] < (z - 2\sqrt{f_E}) \tag{15}$$

That is, (15) defines the set A^M whenever $\hat{c}$, z, f_E and/or f_I are functions of a. When (15) holds, if the incumbent exits with probability one, then the entrant will enter whenever $c \le c^m = (z - 2\sqrt{f_E})$, making it optimal for the incumbent to exit with probability zero. While if the incumbent exits with probability zero, then the entrant will enter only if $c \le c^d = (1/2)(z + c_I - 3\sqrt{f_E})$, making it optimal for the incumbent to exit with probability one. Thus, the equilibrium must have $\hat{c} = c^* = (1/2)[6c_I - 3z - \sqrt{3(36 f_I - (z - 2c_I)^2)}]$ and exit with positive probability less than one.

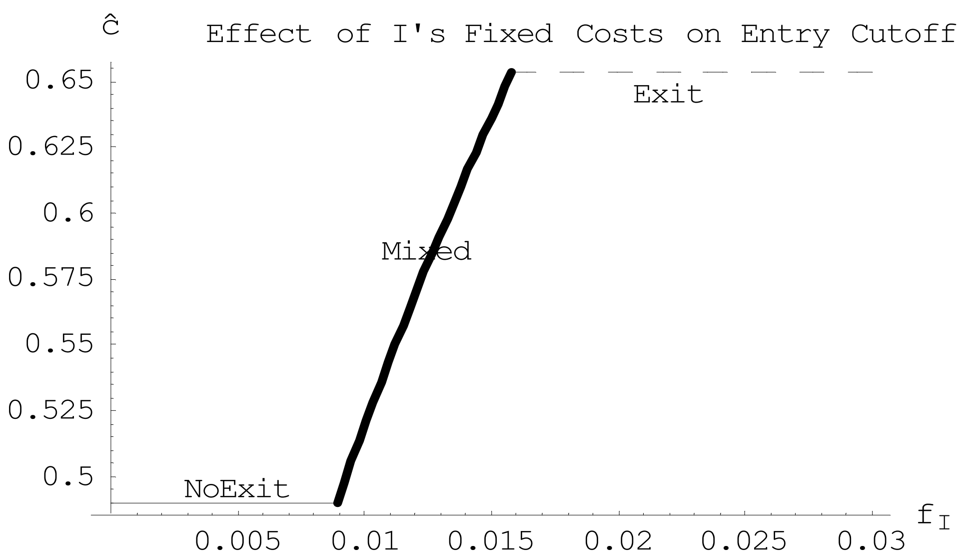
To see how various actions affect the probability of entry in the mixed strategy equilibrium, one need only look at how $c^* = (1/2)[6c_I - 3z - \sqrt{3(36 f_I - (z - 2c_I)^2)}]$ varies with these actions. If the incumbent never exits following entry, however, then the effect of some action on the probability of entry depends on how $c^d = (1/2)(z + c_I - 3\sqrt{f_E})$ varies with this action. For example, say the incumbent's period 1 action increases the entrant's fixed entry cost, that is, $f_E(a)$. If (15) holds for $f_E = f_E(0)$ (the incumbent takes no action to increase entry costs), then, unless the incumbent increases entry costs enough that $(1/2)[6c_I - 3z - \sqrt{3(36 f_I - (z - 2c_I)^2)}] \ge (z - 2\sqrt{f_E})$, the incumbent must still play a mixed exit strategy. As a result, the probability of entry, the probability that $c < c^* = (1/2)[6c_I - 3z - \sqrt{3(36 f_I - (z - 2c_I)^2)}]$, does not change, since c^* is independent of f_E. Increases in entry cost only reduce the probability of entry when entry costs are low enough or high enough that (15) does not hold, in which case the cutoff level for c, $\hat{c}$, is given by c^d or c^m. As (11) and (12) show, increasing f_E does decrease both c^d and c^m. Figure 4 illustrates this for $z = 1, c_I = 1/2, f_I = .01$. (In the next four figures, the region where the incumbent does not exit after entry is denoted by a solid thin line; the mixed exit strategy region is denoted by a thick solid line; and the exit with probability one region is denoted by a dashed line.)

Figure 4



If the incumbent's action, *a*, decreases its avoidable fixed costs, that is, $f_I(a)$, then it is clear from (11), (12), and (14) that this will deter entry if and only if (15) holds, i.e., if and only if we are in the mixed exit strategy equilibrium (c^d and c^m are independent of f_I, but c^* is increasing in f_I). Figure 5 illustrates this for $z = 1, c_I = 1/2, f_E = .03$:

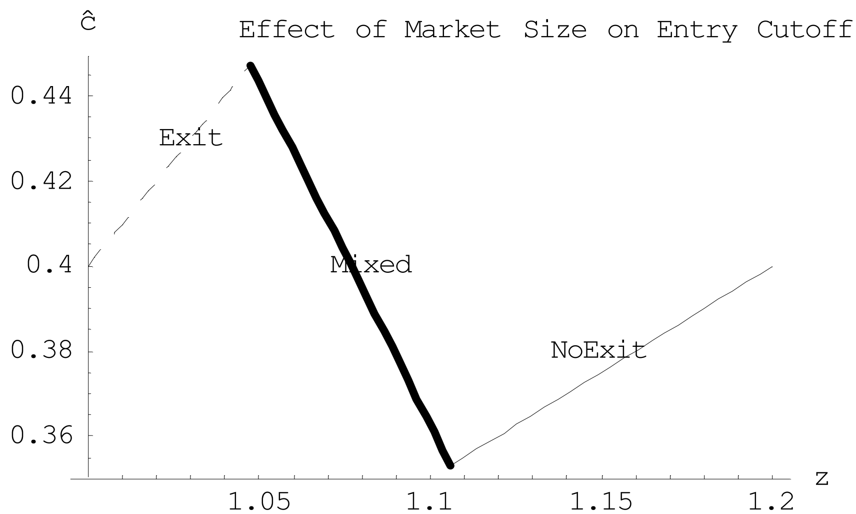
Figure 5



Now consider the case where *a* represents demand-enhancing advertising, that is, *z(a)*. From (11), (12), and (14), one can see that such advertising will deter entry in the mixed strategy equilibrium,

c^* is decreasing in z, but will encourage entry in either the no exit or the always exit equilibrium, both c^d and c^m are increasing in z. Figure 6 illustrates this for $c_I = 1/2, f_I = .01, f_E = .09$:

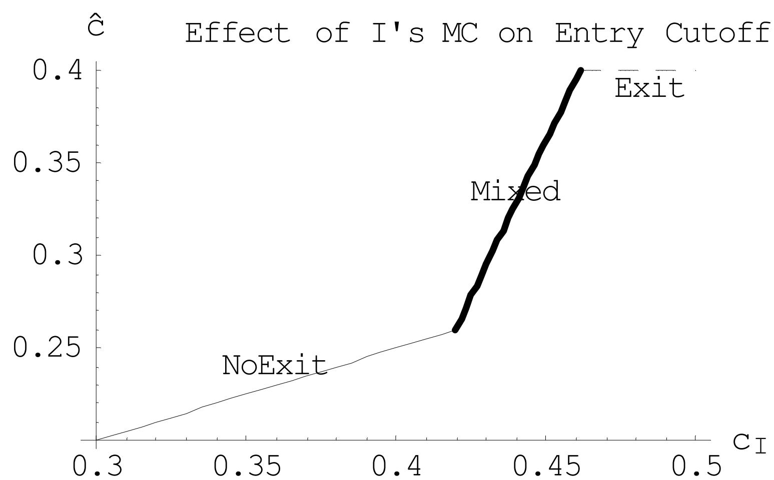
Figure 6



If $z=1$ represents the market size with no period 1 advertising, then small amounts of advertising may be counterproductive since this increases the probability of entry. Larger amounts of advertising that push $z \in (1.05, 1.1)$ will actually decrease the probability of entry because it reduces the probability of exit. Further advertising, however, pushes the incumbent into the never exit equilibrium where advertising begins to encourage entry again. Of course, the optimal amount of advertising will depend on more than just its affect on the probability of entry (this is also true for any of the other actions the incumbent might take to deter entry). But the fact that advertising deters entry in the mixed exit equilibrium but encourages it otherwise suggests that the optimal amount of advertising may often create a mixed exit strategy equilibrium.

Lastly, consider the case where a is an investment in marginal cost reduction, that is, $c_I(a)$. If the incumbent reduces its marginal cost, then this will obviously have no effect on the entrant's entry decision if the incumbent exits whenever there is entry. On the other hand, it will deter entry (reduce the entrant's break-even marginal cost level) if the incumbent never exits after entry since the entrant's duopoly profits are increasing in the incumbent's cost (c^d in (11) is increasing in c_I). In the mixed exit strategy equilibrium, the incumbent's investment in marginal cost reduction will also deter entry, though for a very different reason. Because lower marginal cost increases the incumbent's duopoly profits, the mixed strategy equilibrium must have a lower probability of exit and a smaller marginal cost cutoff for entry the more the incumbent reduces its marginal cost (c^* in (14) is increasing in c_I). Figure 7 demonstrates the effect of the incumbent's marginal cost on entry for $z=1, f_I=.01, f_E=.09$:

Figure 7



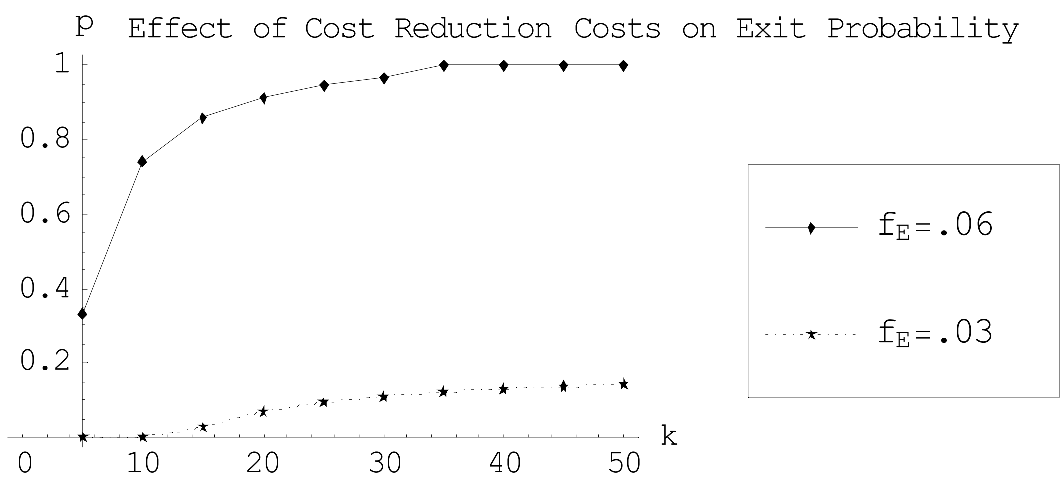
As Figure 7 shows, the incumbent's marginal cost can have a greater effect on the probability of entry in the mixed exit strategy equilibrium than in no exit equilibrium. When this is the case, if the cost of marginal cost reduction increases rapidly, the marginal benefit of investment in cost reduction may exceed its marginal cost in the mixed exit strategy equilibrium, but not if the incumbent reduces its cost so much that it is in the no exit equilibrium. Of course, if cost reduction is relatively cheap, the incumbent may always want to reduce its costs enough that it never exits following entry.

To see that both outcomes are possible, consider the case where the demand curve is stable across periods; the incumbent's first period profit function is identical to its monopoly profit function in the second period (with no cost reduction) less the cost of any cost reducing investment it undertakes. I assume cost reduction costs are quadratic. That is:

$$\pi_{I1}(a)=\frac{(z-c_{I1})^2}{4}-f_I-ka^2 \tag{16}$$

and the incumbent's period 2.3 marginal cost is $c_I = c_{I1} - a$. The incumbent chooses its amount of cost reduction, *a*, to maximize (5) where $\pi_{I1}(a), \pi_{I2d}(a,c)$, and $\pi_{I2m}(a)$ are given by (16), (9), and (10) respectively. $\hat{c}$ is given by c^d if $(1/2)(z + c_I - 3\sqrt{f_E}) > (1/2)[6c_I - 3z - \sqrt{3(36f_I - (z-2c_I)^2)}]$, by c^m if $(1/2)[6c_I - 3z - \sqrt{3(36f_I - (z-2c_I)^2)}] > (z - 2\sqrt{f_E})$ and by $c^* = (1/2)[6c_I - 3z - \sqrt{3(36f_I - (z-2c_I)^2)}]$ otherwise. Figure 8 illustrates how the equilibrium exit probability that results from this optimal choice of *a* varies with *k*, the parameter that measures how costly cost reduction is, for $z = 1, c_{I1} = 1/2, f_I = .01, f_E = .06$ and $.03$:

Figure 8



In this example, when investing in cost reduction is not that costly, *k* is small, and entry costs are not too large ($f_E = .03$), then the incumbent reduces its costs enough so that it will never exit. As cost reduction gets more costly, however, the incumbent will not find it profitable to reduce its cost so much that it will never exit. When entry costs are larger, the average entrant is a tougher competitor, ceteris paribus, so even when cost reduction is relatively cheap the incumbent still plays a mixed exit strategy. And when cost reduction becomes quite expensive, the incumbent's costs, even after optimal cost reduction, are so large that it always exits after entry.

V. THE MIXED EXIT STRATEGY EQUILIBRIUM

V.1 ANALYSIS OF THE MIXED STRATEGY EQUILIBRIUM

If *I* plays a mixed exit strategy, then, as we saw in the above examples, what constitutes effective entry deterrence can be very different from when exit is never optimal (or always optimal). This section shows that this result holds for arbitrary demand and cost functions and arbitrary period 2.3 competitive interaction so long as the profit functions satisfy the properties assumed in Section II. In the no exit benchmark case, the cutoff level for entry is given by $c^d(a)$; the entrant's marginal costs must be low enough that it can cover its fixed costs as a duopolist. I determine the effectiveness of *a* at deterring entry in this case, $a \in A^N$, by differentiating the first equation in (3) with respect to *a* and solving for $c'^d(a)$:

$$c'^d(a) = -\frac{d(\pi_{E2d}(a, c^d(a)))}{da} \bigg/ \frac{d\pi_{E2d}(a, c^d(a))}{dc} \tag{17}$$

Since the denominator is negative, this has the sign of $\dfrac{d(\pi_{E2d}(a, c^d(a)))}{da}$. If the incumbent never exits, then increasing *a* decreases the probability of entry if and only if increasing *a* decreases the entrant's duopoly profits. This is the standard story about how an incumbent deters entry.

To see how entry deterrence in the mixed strategy equilibrium ($a \in A^M$) differs, recall that, because *I* earns zero expected duopoly profits, the cutoff level for entry is given by the $c*$ that solves:

$$\int_{\underline{c}}^{c*} \pi_{I2d}(a, c) g(c) dc = 0 \tag{18}$$

(Because $\hat{c}(a) = c*(a)$ must also satisfy (2) whenever $c*(a) \in (\underline{c}, \overline{c})$, the probability of exit in the mixed strategy equilibrium must be: $p(a) = \dfrac{\pi_{E2d}(a, c*(a))}{\pi_{E2d}(a, c*(a)) - \pi_{E2m}(a, c*(a))}$.)[7]

Now, differentiate (18) with respect to *a* and solve for $c*'(a)$:

[7] If the entry cutoff is not in the interior of the support, then this exit probability is only an upper or lower bound.

$$c^{*\prime}(a) = -\frac{\int_{\underline{c}}^{c^*(a)} \frac{\partial \pi_{I2d}(a,c)}{\partial a} g(c)dc}{g(c^*(a))\pi_{I2d}(a,c^*(a))} \tag{19}$$

This has the sign of $-\frac{\partial \pi_{I2d}(a,c)}{\partial a}$ since $\pi_{I2d}(a,c^*(a)) > 0$ (if the incumbent is to have zero expected duopoly profits, then, because $\pi_{I2d}(a,c)$ is increasing in *c*, it must make positive net profits when the entrant is of the highest possible cost type). Increasing *a* (when $a \in A^M$) reduces the probability of entry if and only if increasing *a* increases the incumbent's net duopoly profit. This proves the following proposition.

Proposition 1. For all $a \in A^M$, if the incumbent cannot commit not to exit, then it can reduce the probability of entry if and only if it increases its expected duopoly profit. When the incumbent can commit not to exit or when $a \in A^N$, however, it can reduce the probability of entry if and only if it reduces the duopoly profit of the break-even entrant.

Proposition 1 demonstrates that the results from the examples of the last section hold more generally. To prove this proposition, I did not make any assumptions about the distribution of the entrant's cost parameter. While I have assumed that the entrant's production technology can be summarized by a single cost parameter, the proof does not make any specific assumption about how production costs vary with this cost parameter (other than the assumptions about how the entrant and incumbent's profits vary with *c*). The proof does use the assumptions that the entrant's profit is decreasing in *c* and the incumbent's duopoly profit is increasing in *c*. These assumptions, however, are quite intuitive and should hold for almost all standard models of competitive interaction.

The distinction Proposition 1 makes between the mixed strategy case and the benchmark case is fundamental. When exit is possible and the incumbent plays a mixed exit strategy, the effectiveness of an entry deterrence action depends only on how it affects the incumbent's profits, not the entrant's. Because increasing the entrant's entry cost does not affect the incumbent's duopoly profits, it has no affect on the probability of entry in the mixed exit strategy equilibrium. By the same token, decreasing the incumbent's avoidable fixed cost will deter entry when the incumbent plays a mixed exit strategy, but not otherwise, since it increases the incumbent's duopoly profits but does not affect the entrant's duopoly profits.

Unlike strategies that affect fixed costs, investments in marginal cost reduction or quality enhancement are entry-deterring strategies in both the mixed exit strategy equilibrium and in the no exit equilibrium. Similarly, both raising the entrant's marginal costs and reducing its quality are effective entry-deterring strategies in either situation. Nonetheless, the possibility of exit is still relevant to these strategies. When exit is never optimal, the entry-deterring payoff from marginal cost reduction comes exclusively from how this will reduce the profitability of entry. If the incumbent might exit, over some regions its investments in marginal cost reduction will deter entry because they increase its own profitability, reducing the probability that it will exit. Therefore, while the direction of the effect of cost reduction on entry is identical in either case, the magnitude of this effect may differ substantially, which will affect the optimal investment in cost reduction.

This distinction is even more critical when one considers the operation of advertising as an entry barrier. If the goods of the incumbent and the entrant are not highly differentiated, one might think that the incumbent would want to refrain from advertising to increase the size of the market because that might induce entry. This is true when the incumbent will never exit. When the incumbent plays a mixed exit strategy, however, the exact opposite is the case. The incumbent will want to advertise to increase the size of the market, not only because doing so increases its profit the period 2, but also because it will deter entry. In this case, entry deterrence occurs because advertising has made the incumbent's threat to remain in the market more credible. A similar argument would apply to investments in quality enhancement that are non-rival (that improve the entrant's quality as much as the incumbent's). This effect is similar to Nalebuff's (1987) point about the importance of credibility in pretrial settlement negotiations.

Notice that in this model, when $a \in A^M$, there will necessarily be more entry when exit is possible than when it is never optimal, as in Bagwell and Ramey (1996). This follows because the condition for the entry cutoff without exit, the first equation in (3), says that all entrant types that can make non-negative duopoly profits will enter. When exit might occur, however, the entrant's profits from entry are a weighted average of duopoly and monopoly profits. Since monopoly profits exceed duopoly profits, higher cost entrants will enter when exit happens with positive probability.

This does not necessarily imply that the incumbent will make less effort to deter entry when exit is possible than it would if it could commit not to exit (where more effort is defined as a greater level of *a*, and thus more first period profits foregone). In fact, there is no clean comparison of the incumbent's incentives to forego profits to deter entry in these two cases because the entry deterrence mechanism is so different when the incumbent might exit versus when it will not. This can be seen by examining the marginal profit from the entry deterrence action, *a*, when the incumbent might exit versus when it can commit not to exit.[8] In the mixed exit strategy case, the marginal profit from *a* is the following:

$$\Pi'_I(a) = \pi'_{I1}(a) + \beta\{(1 - G(c^*(a)))\pi'_{I2m}(a) - c^{*\prime}(a)g(c^*(a)))\pi_{I2m}(a)\} \quad (20)$$

This follows from differentiating (5) with respect to *a*, while fixing the incumbent's profit when there is entry at zero. By substituting in for $c^{*\prime}(a)$ using equation (19), this becomes:

$$\Pi'_I(a) = \pi'_{I1}(a) + \beta\{(1 - G(c^*(a))\pi'_{I2m}(a) + \frac{\pi_{I2m}(a)}{\pi_{I2d}(a, c^*(a))}\int_{\underline{c}}^{c^*(a)}(d\pi_{I2d}(a,c)/da)g(c)dc\} \quad (21)$$

As (21) indicates, *a* increases second period profits in two ways. First, when the entrant won't enter anyway, *a* increases monopoly profits. Second, when the entrant would have entered, *a* increases duopoly profits. That is valuable, however, not because of the added profits given entry (that has to remain at zero to maintain the equilibrium), but because, by reducing the incumbent's incentive to exit, it

[8] I prove the following claim in the Appendix. It establishes that comparing the marginal profit from *a* in the two different cases (the incumbent plays a mixed exit strategy versus the incumbent can commit not to exit) is sufficient to determine in which case the optimal *a* is larger, even if the profit function is not single-peaked. *Claim: Consider two different profit functions* $\Pi_{I,Y}(a)$ *and* $\Pi_{I,Z}(a)$. *If* $\Pi'_{I,Y}(a) > \Pi'_{I,Z}(a)$ *for all a, then the a that maximizes* $\Pi_{I,Y}(a)$ *is larger than the a that maximizes* $\Pi_{I,Z}(a)$, *even if neither* $\Pi_{I,Y}(a)$ *nor* $\Pi_{I,Z}(a)$ *is single-peaked.*

deters entry. From (21), one can see that the entry deterrence value from a is strictly greater than the amount by which it increases duopoly profits (since monopoly is more profitable than duopoly).

In the mixed strategy equilibrium, the marginal profit from a is independent of its effect on the entrant's profit. This is very different from the incumbent's marginal benefit from a when the incumbent will not exit. The marginal return to a in this case is:

$$\Pi_I'(a) = \pi_{I1}'(a) + \beta\{(1 - G(c^d(a))\pi_{I2m}'(a) + \int_{\underline{c}}^{c^d(a)} (d\pi_{I2d}(a,c)/da)g(c)dc + g(c^d(a))[\pi_{I2m}(a) - \pi_{I2d}(a,c^d(a))]c'^d(a)\} \tag{22}$$

With no exit, the incumbent's incentive to increase a will come more (relative to the mixed strategy case) from a's effect on its monopoly profits in period 2 than from its effect on duopoly profits. This occurs not only because there is less entry when the incumbent does not exit, but also because the effect on duopoly profits receives greater weight in (21) than (22). The reason is that, in the mixed exit strategy case, increasing duopoly profits is valuable because it deters entry, which is worth more than the added increment to profit itself. Equation (22), however, has an added entry deterrence term of its own. From equation (17), we know that $c'^d(a) < 0$ if and only if a reduces the entrant's profits. Thus, whether an incumbent has a greater incentive to increase a when it plays a mixed exit strategy than it does when it never exits depends on how strongly a affects the entrant's profits. If the action a has either no effect on the entrant's profits or increases them (e.g., if it is advertising that expands the market), then it is much more likely that the incumbent will choose a larger a when exit is possible.

Focusing on the case where a is a cost reducing investment, one might also wonder if the threat of entry increases or reduces the incumbent's incentive to reduce costs? In the mixed strategy case, one can look at (21) to answer this question. The marginal benefit from a in (21) can be separated into two different terms:

$$\Pi_I'(a) = \pi_{I1}'(a) + \beta\pi_{I2m}'(a) + \beta\int_{\underline{c}}^{c^*(a)} [\frac{d\pi_{I2d}(a,c)}{da}\frac{\pi_{I2m}(a)}{\pi_{I2d}(a,c^*(a))} - \pi_{I2m}'(a)]g(c)dc \tag{21′}$$

The first two terms of the right hand side give the marginal benefit from *a* if there is no threat of entry. The integral term is an adjustment in the marginal benefit due to the threat of entry. The threat of entry will increase the incumbent's incentive to reduce costs if and only if this term is positive.

One can perform the same decomposition of the incentive to reduce costs in the no exit case:

$$\Pi'_I(a) = \pi'_{I1}(a) + \beta\pi'_{I2m}(a) +$$
$$\beta\int_{\underline{c}}^{c^d(a)} \{\frac{d\pi_{I2d}(a,c)}{da} - \pi'_{I2m}(a)\} g(c)dc - \beta g(c^d(a))[\pi_{I2m}(a) - \pi_{I2d}(a, c^d(a))]c'^d(a) \tag{22′}$$

As before, the threat of entry increases the incumbent's incentive to reduce costs if and only if the last line of (22′) is positive. With completely abstract profit functions, it is not possible in either case to say if the threat of entry increases or decreases cost reduction incentives. If profits in period 2.3 are determined by a standard one-shot Cournot quantity-setting game with constant and known marginal costs,[9] however, then one can definitively answer this question.

Consider Cournot competition where the entrant's marginal cost is *c* (unknown to the incumbent in period 2.2 but revealed in period 2.3). The incumbent's marginal cost in period 1 is c_I, and its marginal cost in period 2.3 is $c_I - a$. Period 2.3 profit functions are as follows:

$$\pi_{I2d}(a,c) = p(q_{Id} + q_d)(q_{Id} - (c_I - a)) \tag{23}$$

$$\pi_{E2d}(c) = p(q_{Id} + q_d)(q_I - c) \tag{24}$$

In (23) and (24), q_{Id} and q_d Cournot-Nash equilibrium quantities given *a* and *c*. With this setup, I can now prove the following proposition.

Proposition 2. Say $p' < 0$ and $p'' \le 0$ *and the threat of entry creates a mixed exit strategy equilibrium,* $a \in A^M$ *. If period 2.3 profit functions are given by (23) and (24), then the threat of entry*

[9] Since the incumbent does not know the entrant's marginal cost in period 2.2, this requires that the incumbent learns the entrant's marginal cost between period 2.2 and period 2.3. While this assumption is implausible in many cases, as mentioned above, it is not necessary for this result (a proof of this is available upon request).

strictly increases the incumbent's incentive to reduce costs when the entrant's cost parameter is revealed prior to period 2.3.

Proof. See Appendix.

Proposition 1 drives this result. A duopoly market can reduce the incentive for cost reduction vis-à-vis a monopoly one because the incumbent produces less output. However, when the incumbent plays a mixed exit strategy, its benefit from cost reduction in a duopoly market arises solely from the increase in the credibility of its threat not to exit, which increases the probability that it will remain a monopolist. Because of this, the magnitude of this benefit depends on the entire monopoly output. Moreover, the benefit is not just the reduced cost but also the larger price the incumbent gets when it is a monopolist rather than a duopolist. As a result, the threat of entry strictly increases the incumbent's incentive to reduce costs so long as the effect on duopoly profits is large enough. If duopoly competition takes the Cournot form, then this is always the case.

When the incumbent never exits, the threat of entry can either increase or decrease the incumbent's cost reduction incentives under Cournot competition. The appendix provides an example that demonstrates this using a linear inverse demand curve and a uniform distribution of entrant types. The reason for the ambiguity is that the entry deterrence benefit from cost reduction is (as Proposition 1 demonstrates) completely independent of the duopoly benefit from cost reduction. Thus, if the entry deterrence benefit is small (either because cost reduction has a small effect on the entrant's profits or because monopoly and duopoly profits do not differ by much), then it is possible for the threat of entry to decrease the incumbent's incentive to reduce costs.

V.2 ROBUSTNESS OF THE MIXED STRATEGY EQUILIBRIUM

One might object to the foregoing analysis by arguing that even though there are values of a for which I must play a mixed exit strategy, there may not be reasonable circumstances where I will indeed choose such a value of a. This objection is misguided on three counts. First, Proposition 1 will often affect the incumbent's choice of a even when that choice doesn't lead to a mixed exit strategy. For example, consider I's decision about whether to lobby for new plant regulations that will increase entry costs. If exit were never optimal (or, *I* could commit not to exit), any level of lobbying effort could be optimal. When this isn't the case, Proposition 1 says that while *I* may try to increase entry costs up to the point where it has to play a mixed exit strategy, it has no incentive for further marginal increases in entry costs. Only a discrete jump in the level entry costs that moves *I* out of the mixed exit strategy equilibrium and into the always exit equilibrium could be optimal.

Second, one can also think of Proposition 1 as a comparative statics result for exogenous parameter changes. For example, Proposition 1 tells us that larger entry costs will not necessarily decrease the probability of entry. On the other hand, reductions in avoidable fixed costs can sometimes have a dramatic impact on the probability of entry. Third, the prior section provided examples where choosing $a \in A^M$ was optimal for a range of parameter values (for the cost reduction case). While these are only examples, since $c^d < c^m$ (monopoly is strictly more profitable than duopoly), there exists a cost function for any action, *a*, that deters entry in the mixed strategy equilibrium such that $a \in A^M$ is optimal whenever A^M is non-empty. (If the marginal cost of this action is close to zero for all $a < \inf(A^M)$ but rises very rapidly when $a \in A^M$, then *I* will always want to choose an *a* that generates a mixed exit strategy equilibrium.)

One might also wonder how sensitive the results in Proposition 1 are to the need for a mixed strategy equilibrium. To shed light on this question, consider introducing some demand uncertainty, so that the incumbent never plays a mixed exit strategy. Say that in period 2.2, prior to making its exit decision, the incumbent observes a small, mean zero, shock, *s*, to its demand. (For simplicity, assume this does not affect the entrant's demand.) Then, instead of an incumbent being indifferent about exit, if the incumbent gets a favorable cost shock (say $s > s^*$) it remains in the market, otherwise it exits.[10]

For an action, *a*, that only reduces the profitability of entry, there will be a small effect on the entry cutoff level. To see this, suppose that the entry cutoff is unaffected. Then the incumbent's expected duopoly profits are unchanged, so it still remains in the market if and only if $s > s^*$. Now, an entrant

[10] I thank Ezra Friedman for suggesting this case.

whose cost parameter is exactly at the old cutoff level will no longer break even (since the incumbent chose an action *a* that reduced the entrant's profitability) and so will not enter. This reduces the cutoff level for entry, so s^* must increase (the average entrant has lower costs, so the incumbent needs a better demand shock to make zero expected profits). The increase in s^*, however, increases the probability that the entrant will be a monopolist, which increases the profitability of entry. Thus, the cutoff level for entry cannot fall by as much as it would if there were no exit. That is, the possibility of exit still reduces the ability of profit reducing strategies to deter entry, though it does not entirely eliminate their effectiveness.

As the magnitude of the demand uncertainty goes to zero, however, the effectiveness of reducing the profitability of entry does approach zero. If the distribution of demand shocks is very tightly clustered, then it only takes a very small reduction in the cutoff level of entry to cause a big shift in the probability of exit (because the accompanying small change in s^* has a large effect on the probability of exit when demand shocks are very small). While stark nature of Proposition 1 depends on the endogenous uncertainty of the mixed strategy equilibrium, qualitatively similar results arise with demand uncertainty.[11]

In addition, introducing this uncertainty will not change the fact that actions that only increase the duopoly profit of the incumbent deter entry. (When duopoly is more profitable for the incumbent, it does not require as favorable a demand shock to remain in the market. This reduces the probability that the entrant will be a monopolist, making entry less profitable.) Whether or not a strategy, such as advertising, that increases profitability for both the incumbent and the entrant deters entry will depend on the magnitude of the uncertainty. The smaller the demand uncertainty, the more likely advertising will deter entry rather than encourage it.

One could also object to the robustness of the results by arguing that if the incumbent and the entrant compete for many periods following entry, the incumbent might never exit until it learned the entrant's costs. It is far from certain, however, that the incumbent would necessarily learn the entrant's

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[11] Profit reducing strategies will be less effective at deterring entry when the entrant's cost parameter has a large effect (relative to the demand shock) on the incumbent's duopoly profits.

costs through duopoly competition. Just as there are pooling as well as separating equilibria in the Milgrom and Roberts (1982) limit pricing model, there could be pooling equilibria here where the entrant's production and pricing decisions are independent of its costs.

Moreover, even if there is a separating equilibrium, exogenous factors such as cost or demand shocks might slow the incumbent's learning dramatically, making the benefits of acquiring further information not worth the expected current production losses. This is especially true given that separating equilibria typically require low cost types to behave more aggressively than in a myopic setting, making information acquisition that much more costly. Thus, while allowing for more periods of potential competition could decrease the range of parameters for which there will be a mixed exit strategy equilibrium, it will by no means eliminate this equilibrium. The results from the two period model still provide valuable insights for the multi-period case.

VI. CONCLUSION

When there are fixed costs that can be avoided by exit, exit will sometimes be the incumbent's ex post profit-maximizing strategy. This paper shows that considering this possibility can significantly alter the ability of entry deterring strategies to deter entry credibly. These credibility issues could be particularly important in industries where technology is rapidly advancing, making the risk that an entrant could supplant an incumbent quite large. Even where the incumbent might compete with the entrant for more than one period following entry, as discussed briefly above, the qualitative effects of the possibility of exit will often be similar. A complete description of such a multi-period model is left for future research.

APPENDIX

Proof of Claim. Say, contrary to the Claim, that $a_Y^* = \arg\max \Pi_{I,Y} < a_Z^* = \arg\max \Pi_{I,Z}$, while $\Pi'_{I,Y}(a) > \Pi'_{I,Z}(a)$ for all a. I can write $\Pi_{I,Y}(a_Z^*) - \Pi_{I,Y}(a_Y^*) = \int_{a_Y^*}^{a_Z^*} \Pi'_{I,Y}(a)da$ and $\Pi_{I,Z}(a_Z^*) - \Pi_{I,Z}(a_Y^*) = \int_{a_Y^*}^{a_Z^*} \Pi'_{I,Z}(a)da$. Using these, the fact that $a_Y^* < a_Z^*$ implies that:

$$\Pi_{I,Y}(a_Z^*) - \Pi_{I,Y}(a_Y^*) - (\Pi_{I,Z}(a_Z^*) - \Pi_{I,Z}(a_Y^*)) = \int_{a_Y^*}^{a_Z^*} (\Pi'_{I,Y}(a) - \Pi'_{I,Z}(a))da > 0$$

Thus, $\Pi_{I,Y}(a_Y^*) - \Pi_{I,Y}(a_Z^*) < \Pi_{I,Z}(a_Y^*) - \Pi_{I,Z}(a_Z^*)$. But $\Pi_{I,Z}(a_Y^*) - \Pi_{I,Z}(a_Z^*) < 0$ since a_Z^* maximizes $\Pi_{I,Z}$ and $\Pi_{I,Y}(a_Y^*) - \Pi_{I,Y}(a_Z^*) > 0$ since a_Y^* maximizes $\Pi_{I,Y}$, a contradiction. Q.E.D.

Proof of Proposition 2. From equation (21′), the threat of entry will increase the incumbent's incentive to reduce costs if:

$$\frac{d\pi_{I2d}(a,c)}{da}\frac{\pi_{I2m}(a)}{\pi_{I2d}(a,c^*(a))} - \pi'_{I2m}(a) > 0, \forall c \in [\underline{c}, \hat{c}(a)] \tag{A1}$$

Without loss of generality, I measure the cost reducing investment by the magnitude of the cost reduction. Hence, the incumbent's period 2 marginal cost is $c_I - a$. Using the fact that duopoly profits are determined by a one-shot Cournot quantity setting game, the left hand side of (A1) is:

$$q_{Id}(1 - p'_d \frac{\partial q_d}{\partial q_{Id}} \frac{\partial q_{Id}}{\partial c_I}) \frac{q_{\mathrm{Im}}(p_{\mathrm{Im}} - (c_I - a))}{q_{Id}(p_d - (c_I - a))} - q_{\mathrm{Im}} \tag{A2}$$

The arguments are suppressed in the above expression. All price terms and their derivatives are functions of the total quantity produced and q_d represents the entrant's duopoly quantity. Expression (A2) is positive if and only if the following inequality holds:

$$(1 - p'_d \frac{\partial q_d}{\partial q_{Id}} \frac{\partial q_{Id}}{\partial c_I}) \frac{(p_{\mathrm{Im}} - (c_I - a))}{(p_d - (c_I - a))} > 1 \tag{A3}$$

The second fraction on the left hand side is greater than one since monopoly prices are greater than duopoly prices. Thus, (A3) will hold if $\frac{\partial q_{Id}}{\partial c_I} < 0$ and $\frac{\partial q_d}{\partial q_{Id}} < 0$ since $p'_d < 0$. It is well known that

$\frac{\partial q_{Id}}{\partial c_I} < 0$ under Cournot competition with known costs. To show that $\frac{\partial q_d}{\partial q_{Id}} < 0$, I use the entrant's first order condition under Cournot competition:

$$p(q_{Id} + q_d) + q_d p'(q_{Id} + q_d) - c = 0 \tag{A4}$$

Differentiating this with respect to q_{Id} and solving for $\frac{\partial q_d}{\partial q_{Id}}$ gives the following:

$$\frac{\partial q_d}{\partial q_{Id}} = -\frac{p'(q_{Id} + q_d) + q_d p''(q_{Id} + q_d)}{2p'(q_{Id} + q_d) + q_d p''(q_{Id} + q_d)} < 0 \tag{A5}$$

Q.E.D.

Example: Entry can either increase or decrease cost reduction incentives without exit

To show that, if exit is not possible, the threat of entry can either increase or decrease the incumbent's incentive for cost reduction, under Cournot competition, consider a linear inverse demand function and a uniform distribution of entrant types. That is, let $p(q) = z_1 - z_2 q$ and let $c \sim U(c_L, c_H)$. The assumption of Cournot competition with these functional forms gives the following explicit forms for the profit functions:

$$\begin{aligned} \pi_{I2d}(a,c) &= \frac{(z_1 - (2(c_I - a) - c))^2}{9z_2} - f; \pi_{I2m}(a) = \frac{(z_1 - (c_I - a))^2}{4z_2} - f \\ \pi_{E2d}(a,c) &= \frac{(z_1 - (2c - (c_I - a)))^2}{9z_2} - f_E; \pi_{E2m}(c) = \frac{(z_1 - c)^2}{4z_2} - f_E \end{aligned} \tag{A6}$$

Using these profit functions and solving the first equation in (3) for $c^d(a)$ gives the following:

$$c^d(a) = \frac{1}{2}(c_I - a + z_1 - 3\sqrt{f_E z_2}) \tag{A7}$$

Using (A6) and (A7), I can write the last two lines of (22′), the added marginal benefit of cost reduction due to the threat of entry, as follows:

$$\frac{\beta\{27 f_E z_2 + 2(z_1 + (c_I - a) - 2c_L)(z_1 - 5(c_I - a) + 4c_L)\}}{72 z_2 (c_H - c_L)} \tag{A8}$$

Expression (A8) is positive if and only if:

$$\frac{1}{5}\{5c_I - 7c_L + 2z_1 - 3\sqrt{(z_1 - c_L)^2 + \frac{15f_E z_2}{2}}\} < a$$
$$< \frac{1}{5}\{5c_I - 7c_L + 2z_1 + 3\sqrt{(z_1 - c_L)^2 + \frac{15f_E z_2}{2}}\} \tag{A9}$$

Thus, when exit is not possible, with these functional forms, the threat of entry will decrease the incumbent's incentive to reduce costs when the optimal amount of cost reduction is either very large or very small. This is more likely if the first period cost of cost reducing investment is very small or very large. For example, when the parameters take on the following values:

$$c_I = 3.5, c_L = 0, c_H = 7, z_1 = 5, z_2 = 1, f_E = 1, \beta = .95$$

the threat of entry reduces the incumbent's incentive to reduce costs when the first period loss from cost reduction is $-a^2$, but increases the incumbent's incentive to reduce costs when this loss is given by $-.4a^2$. Q.E.D.

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