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ENTRY DETERRENCE WITH UNCERTAIN ENTRY AND UNCERTAIN OBSERVABILITY OF COMMITMENT*

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The standard approach to the issue of strategic entry deterrence is based on the assumption that if the incumbent does not precommit entry will take place with certainty, while if he does precommit entry will be deterred with certainty. In this note we allow for the possibility that the opportunity cost of entry is random, so that entry is not a priori certain. We also allow for the possibility that the incumbent's commitment is not observed by the potential entrant. We show in numerical examples that even very little uncertainty may be sufficient to induce the incumbent not to attempt to deter entry.

1. Introduction

The standard approach to the issue of strategic entry deterrence is to postulate a three-stage game between an incumbent monopolist and a potential entrant, where in stage 1 the incumbent decides whether or not to sink costs which will reduce the profitability of entry, in stage 2 the potential entrant decides whether or not to enter and in stage 3, if entry has occurred, some form of competition takes place between the two firms. The standard assumption is that entry takes place if and only if the entrant expects to make positive profits.[1] A subgame-perfect equilibrium of the game, therefore, will be characterized by entry deterrence if and only if the sunk cost faced by the incumbent has the effect of reducing the entrant's profits to a non-positive level and is such that duopoly profits are less than the difference between monopoly profits and the sunk costs itself [see, for example, Dixit (1982)].

One of the problems with this approach is that it ignores two forms of uncertainty which seem to be relevant in real markets. The first source of uncertainty is the presence of alternative forms of investment for the potential entrant (e.g. entry into another market, financial assets, etc.). If the

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[1]Or profits which are greater than the opportunity cost of entry, which is assumed to be known from the start and less than duopoly profits.

return which can be obtained on alternative investments (i.e. the opportunity cost of entry into a given market) is a random variable, the incumbent will be faced with *uncertain* entry and might not be willing to sink costs in an entry-deterring strategy when entry may not take place after all. Furthermore, the incumbent's decision whether or not to deter entry will now depend crucially on his discount rate.

The second source of uncertainty concerns the 'rationality' of the potential entrant. The standard approach implies that if the incumbent sinks costs which have the effect of making entry unprofitable, then the potential entrant will anticipate the effects of the incumbent's action correctly and refrain from entering.[2] In reality, however, the incumbent cannot be sure that his commitment will be observed and/or that its effects will be correctly assessed by the potential entrant.[3] In other words, in the population of potential entrants there may be some (although, presumably, few) who do not spend enough time and/or resources in carefully assessing the profitability of the market they plan to enter (and base their decision on easily observed data, such as the incumbent's profits), or do not fully appreciate the effects of advertising on consumer loyalty, or make a mistake in evaluating the incumbent's capacity or commitment to fight entry, etc. If there is a positive (although, presumably, small) probability that the potential entrant fails to observe the incumbent's commitment or makes a mistake in assessing its effects, then the latter may be unwilling to sink costs which might not have the desired entry-deterring effect and lead instead to considerable losses.

In the following section we analyse, in a simple model, the effects of these two forms of uncertainty, while in section 3 we give an example which shows that even a very small amount of uncertainty may be sufficient to 'deter the incumbent from attempting to deter entry'.[4] Section 4 contains some final remarks and a conclusion.

2. The model

We shall consider a simple model along the lines of the one introduced by Dixit (1982). At time -3 the incumbent decides whether to be passive or

[2] These sunk costs may take the form of advertising, excess capacity, exclusive dealerships, etc.: cf. Salop (1979) and Dixit (1982) and the references given there.

[3] This possibility was also mentioned by Milgrom and Roberts (1982, p. 303).

[4] The conclusion that uncertainty reduces the chances that the incumbent will opt for entry deterrence, was also reached by Maskin (1986) [see also Perrakis and Warskett (1983)]. However, the type of uncertainty considered by him is different to ours and concerns demand and costs. In Maskin's model the incumbent moves first and chooses its capacity level; the entrant then moves and either chooses to stay out of the market or else selects a level of capacity; after capacity is installed, firms observe the realization of a random variable which affects demand and costs and then choose output levels simultaneously. One of the results is that the introduction of a small amount of uncertainty either does not affect the incumbent's choice between deterrence and accommodation or else induces it to switch away from deterrence.

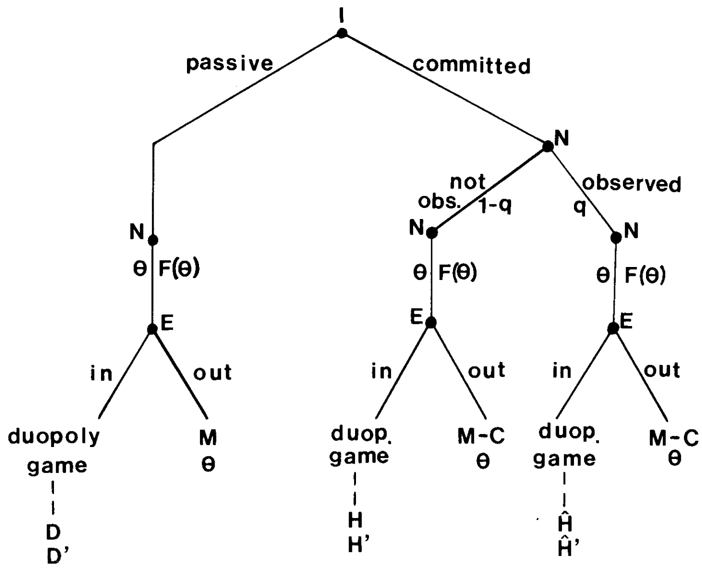

Fig. 1. *I* stands for Incumbent, *E* for Entrant and *N* for Nature. *M* denotes monopoly profits, *C* the commitment cost and θ the opportunity cost of entry. *D* and *D'*, *H* and *H'*, and $\hat{H}$ and $\hat{H}'$ are the incumbent's and entrant's profits, respectively, at the Nash equilibrium of the corresponding duopoly game.

committed. At time -2 Nature selects the value of the random variable θ according to the probability distribution $F(\theta)$, where θ represents the maximum profits which the potential entrant can make by investing in another sector of the economy (that is, the opportunity cost of entry). If the incumbent decided to commit, Nature also selects (at time -2) one of two possibilities: the commitment is observed by the potential entrant (with probability q) and the commitment is not observed (with probability $1-q$). At time -1 the potential entrant decides whether or not to enter and, finally – if entry occurs – a duopoly game takes place. Payoffs are collected at time 0. Fig. 1 illustrates the game. *M* denotes monopoly profits, *C* the commitment cost and θ the maximum profits which can be obtained in alternative investments (the opportunity cost of entry).

Whenever entry has *not* taken place at time t (e.g., because higher profits can be obtained elsewhere), then the basic game is repeated, where Nature again selects θ, the (same or another) potential entrant decides whether or not to enter, a duopoly game is played if entry occurs and payoffs are collected at time $t+1$. This allows for the possibility that entry is not profitable at time t but becomes so at a later date. For simplicity we assume that the decision whether to be passive or committed is made only once by the incumbent.[5]

[5]There is no loss of generality in this assumption, since in our model all the probabilities are constant over time (see also the comments in the final section).

We shall look at the subgame-perfect equilibria [cf. Selten (1975)] of this (infinite) game and assume that players' decisions are based on expected discounted profits. We shall denote by D and D' the incumbent's and entrant's profits, respectively, at the Nash equilibrium of the duopoly game which follows the incumbent's decision to be passive, and by H and H' (resp. $\hat{H}$ and $\hat{H}'$) their profits at the Nash equilibrium of the duopoly game where the incumbent is committed and the commitment is not (resp. is) observed. Let $[a, b]$ be the support of the probability distribution $F(\theta)$. We assume that

$$\hat{H}' \leqq a, \tag{1}$$

so that if the incumbent is committed and the potential entrant is aware of the commitment, the latter will decide not to enter. Furthermore, we assume that $a < D' < b$, that is,

$$0 < F(D') = \text{Prob}\,\{\theta \leqq D'\} < 1, \tag{2}$$

so that the question whether entry is profitable or not – when the incumbent is passive – is a priori open. Let

$$p \equiv F(D'). \tag{3}$$

Thus p is the probability of entry if the incumbent is passive.

If the incumbent is committed, but the commitment is not observed, the potential entrant will believe that the payoffs are as in the case where the incumbent is passive and expect to obtain a profit of D' if he enters. Therefore entry will take place, in this case, if $\theta \leqq D'$. We shall assume that if entry occurs because the entrant was not aware of the incumbent's commitment, then the former will exit after one period, while the incumbent will remain in the market.[6]

Finally, we assume, for simplicity, that if the incumbent is passive and entry occurs, then there will be a duopoly for ever.[7]

We shall denote by E_c the incumbent's expected discounted profits if he commits and by E_p his expected discounted profits if he is passive.

[6] In other words, when the entrant's profits turn out to be H' rather than (the expected) D', he realizes his mistake and leaves the market. The alternative assumption that the entrant is 'locked' in the market would *reinforce* our results, rather than weaken them. In fact, an entrant who enters because he is not aware of the incumbent's commitment, imposes a cost not only on himself but also on the incumbent, since the latter's profits are reduced, as a consequence of entry, from $(M-C)$ to H (as explained in the introduction, this is why the incumbent will find commitment less attractive than in the standard case where $q=1$). The assumption we have made implies that the entrant's mistake has a negative effect on the incumbent's profits only for *one* period, while the alternative assumption would imply low profits for the incumbent *for ever*.

[7] That is, we assume that the fixed costs of production are such that there is room for two, but not more than two, firms in the market.

Consider first the case where $q=1$, that is, the incumbent's commitment is observed with certainty by the potential entrant(s). In this case

$$E_c\big|_{q=1}=\sum_{t=0}^{\infty}(M-C)\delta^t=(M-C)/(1-\delta), \tag{4}$$

where $\delta\in(0,1]$ is the incumbent's discount factor.

If the incumbent is passive, entry at date 0 will occur with probability p and the corresponding discounted profits for the incumbent will be $\sum_{t=0}^{\infty}D\delta^t$. With probability $(1-p)$ the incumbent will collect monopoly profits at date 0 and we move on to date 1 where, again, entry takes place with probability p with corresponding discounted profits equal to $\sum_{t=1}^{\infty}D\delta^t$, etc. Thus[8]

$$E_p=\frac{pD+(1-\delta)(1-p)M}{(1-\delta)(1-\delta+\delta p)}. \tag{5}$$

Note that when the incumbent is very impatient ($\delta=0$), E_p becomes $[pD+(1-p)M]$.

The incumbent will decide to commit if and only if $E_c>E_p$, that is, if and only if

$$\frac{C}{M-D}<\frac{p}{1-\delta+\delta p}. \tag{6}$$

Note that when $p=1$, that is, when entry is certain, (6) becomes

$$C/(M-D)<1, \tag{7}$$

or $M-C>D$, which is the necessary and sufficient condition for the incumbent to decide to deter entry. For a given $\delta\in(0,1)$, the RHS of (6) is increasing in p (it is equal to 0 when $p=0$ and equal to 1 when $p=1$). Therefore, if the incumbent's discount factor is less than 1, for every triple of values (C,D,M) satisfying (7) there will be a $p^*>0$ such that if $p\leqq p^*$ the incumbent will not want to deter entry (while he would if entry were certain). Similarly, for a given $p\in(0,1)$ the RHS of (6) is increasing in δ (it equals p when $\delta=0$ and 1 when $\delta=1$). Therefore, if (C,D,M) satisfies (7) and $p<[C/$

[8]In fact,

$$E_p=p\textstyle\sum_{t=0}^{\infty}D\delta^t+(1-p)\{M+p\sum_{t=1}^{\infty}D\delta^t+(1-p)[M\delta+p\sum_{t=2}^{\infty}D\delta^t+(1-p)$$
$$\times[M\delta^2+p\textstyle\sum_{t=3}^{\infty}D\delta^t+(1-p)[M\delta^3+\ldots=(1-p)M\sum_{t=0}^{\infty}(1-p)^t\delta^t$$
$$+pD\textstyle\sum_{k=0}^{\infty}(1-p)^k\sum_{t=k}^{\infty}\delta^t=(1-p)M/(1-\delta+\delta p)+pD\sum_{k=0}^{\infty}(1-p)^k\delta^k/(1-\delta)$$
$$=(1-p)M/(1-\delta+\delta p)+pD/[(1-\delta)(1-\delta+\delta p)].$$

$(M-D)$] then there will be a $\delta^*>0$ such that if $\delta \leqq \delta^*$ the incumbent will again refrain from deterring entry. The intuition is clear: *commitment reduces profits with certainty, while entry, which reduces profits from monopoly to duopoly level, is not certain. If the probability of entry (when the incumbent is passive) is sufficiently smaller than 1 and/or the incumbent is sufficiently impatient, commitment will not be desirable.* If the commitment cost C is sufficiently high – so that $C/(M-D)$, while still satisfying (7), is close to 1 – then even a very small probability of no entry (that is, even a p very close to 1) will be sufficient to discourage the incumbent from deterring entry (cf. section 3).

We now consider the case where $q<1$, that is, the case where there is a positive probability, $(1-q)$, that the incumbent's commitment is not observed (or its effects are wrongly assessed) by the potential entrant(s). In this case if the incumbent is passive his expected profits will still be given by (5), while commitment yields expected profits in each period equal to

$$(1-p)(M-C)+p[q(M-C)+(1-q)H]$$
$$=(1-p+pq)(M-C)+p(1-q)H.$$

Thus

$$E_c\big|_{q<1}=\frac{(1-p+pq)(M-C)+p(1-q)H}{(1-\delta)}, \tag{8}$$

(recall the assumption that if entry occurs because the entrant did not observe the commitment, then the latter, having realized his mistake, will exit immediately: cf. footnote 6). Thus the incumbent will commit if and only if $E_c>E_p$, that is, if and only if

$$\frac{C}{M-D}<\frac{p}{(1-p+pq)(1-\delta+\delta p)}-\frac{p(1-q)(M-H)}{(1-p+pq)(M-D)}. \tag{9}$$

When $q=1$, (9) coincides with (6), while when $q<1$, as long as $D>H$, the RHS of (9) is smaller than the RHS of (6). Therefore, *the possibility that commitment is not observed (and thus that it may not be effective in deterring entry) makes the condition for the optimality of commitment even more stringent than before.* Furthermore, it can be shown that, for any given p, the RHS of (9) is an increasing function of δ and (as long as $D>H$) of q. Thus, the higher the probability that commitment is not observed and/or the more impatient the incumbent, the less likely it is that inequality (9) will be satisfied, ceteris paribus.

In the following section we investigate the effects of these two forms of uncertainty in an example.

3. An example

We now apply the results of the previous section to a variant of Dixit's (1980) model of investment in excess capacity, in order to investigate the effects of uncertain entry and uncertain observability of commitment in numerical examples. Let the (inverse) demand function by given by

$$P=1-BQ, \tag{10}$$

(where P is price, Q is output and B is a positive constant). We shall consider the symmetric case where incumbent and entrant face the same average variable cost and the same cost per unit of capacity. Using the same notation as Dixit, the incumbent's cost function is given by

$$c=wx+rk, \tag{11a}$$

where k is capacity, x is output ($x \leq k$), r the constant cost per unit of capacity and w the constant average variable cost for output, while the entrant's cost function is given by

$$c=(w+r)x. \tag{11b}$$

Note that in this version of the model, fixed costs of production are zero, so that *there are no scale economies*.[9]

Let Π denote profits and subscripts 1 and 2 refer to incumbent and entrant, respectively. In fig. 2, $M'M$ is the incumbent's reaction curve when capacity expansion costs matter, $N'N$ when there is spare capacity, while RR' is the entrant's reaction curve (x_i denotes the output of firm i, $i=1,2$).[10]

Let $[a,b]$ be the support of the probability distribution $F(\theta)$. In order to fix our ideas, we shall assume that $a=\Pi_2(V_1, V_2)$, that is

$$a=(1-w-2r)^2/(9B), \tag{12}$$

so that V_1 is the level of capacity which – if observed – deters entry (in terms

[9]Since the argument of this paper does not depend at all on the presence of scale economies, our results have a different basis to the one on which rests Schmalensee's (1981) finding that entry barriers in Dixit-type models are generally of little quantitative importance.

[10]The equation for $M'M$ is given by $x_2=(1/B)(1-2Bx_1-w-r)$, while $N'N$ and RR' are defined by $x_2=(1/B)(1-2Bx_1-w)$ and $x_2=[1/(2B)](1-Bx_1-w-r)$, respectively.

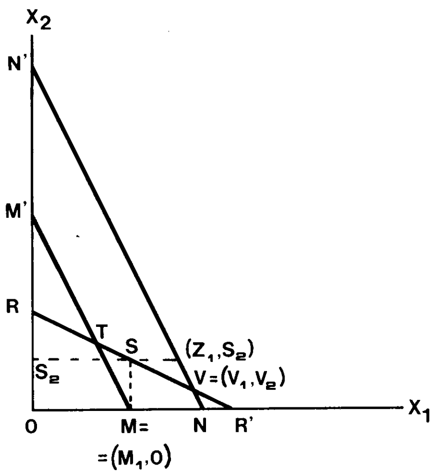

Fig. 2. $x_1(x_2)$ denotes the incumbent's (entrant's) output. RR' is the entrant's reaction curve, $N'N(M'M)$ the incumbent's reaction curve when there is (there is not) spare capacity.

of the notation of section 2, $\Pi_2(V_1, V_2) \equiv \hat{H}'$).[11] If the incumbent chooses capacity V_1 and the potential entrant stays out, the former's profits are given by

$$\Pi_1(V_1, 0) = [2(1-w+r)(1-w-2r)]/(9B). \tag{13}$$

Monopoly profits are given by

$$\Pi_1(M_1, 0) = (1-w-r)^2/(4B), \tag{14}$$

[where $M_1 = (1-w-r)/(2B)$]. If the incumbent decides to accommodate entry, he will choose capacity so as to maximize his profits along the segment TV in fig. 2.[12] Let $S=(S_1, S_2)$ be the corresponding point. Then it can be shown that $S_1 = M_1$, that is, the optimal entry-accommodating choice of capacity for the incumbent coincides with monopoly capacity (and output). The entrant's capacity (and output) would be $S_2 = (1-w-r)/(4B)$ (half the capacity and output of the incumbent). The corresponding duopoly profits for the incumbent are given by

$$\Pi_1(S_1, S_2) = (1-w-r)^2/(8B). \tag{15}$$

Finally, we consider what happens if the incumbent chooses capacity V_1

[11]The coordinates of point V are $V_1 = (1-w+r)/(3B)$ and $V_2 = (1-w-2r)/(3B)$. An alternative assumption could be $a=0$ and $f = \Pi_2(V_1, V_2)$, where f denotes fixed production costs.

[12]The coordinates of point T are $T_1 = T_2 = (1-w-r)/(3B)$.

but the potential entrant is not aware of it. A natural assumption in this case is that the potential entrant believes that the incumbent's capacity equals monopoly capacity and therefore, if he decides to enter, he will do so with his best reply to that, which is S_2 [and will expect to obtain a profit of $\Pi_2(M_1, S_2)$]. The Cournot–Nash equilibrium corresponding to capacity levels V_1 for the incumbent and S_2 for the entrant is at point (Z_1, S_2) where the line of equation $x_2 = S_2$ intersects the $N'N$ line.[13] The corresponding profits for the incumbent are given by

$$\Pi_1(Z_1, S_2) = [9(1-w-r)^2 - 16r^2]/(64B). \tag{16}$$

We can now translate the above into the notation of section 2:

$$M \equiv \Pi_1(M_1, 0), \tag{17a}$$

$$M - C \equiv \Pi_1(V_1, 0), \tag{17b}$$

$$D \equiv \Pi_1(S_1, S_2), \tag{17c}$$

$$H \equiv \Pi_1(Z_1, S_2). \tag{17d}$$

We shall only be interested in the case where (17b) is greater than (17c), that is, $[C/(M-D)] < 1$ [cf. (7)] so that entry deterrence is optimal if entry is certain ($p = 1$) and the incumbent's commitment is observed with certainty ($q = 1$). Using (13)–(15) we obtain

$$C/(M-D) = [2(1-w-5r)^2]/[9(1-w-r)^2]. \tag{18}$$

Note that, therefore, the LHS of (9) is independent of B; it can be shown that this is true also for the RHS of (9).[14] For any triple of values $(\delta, p, q) \in (0,1)^3$, the following is true: (i) for any given r, $[C/(M-D)]$ is *increasing* in w (for $w > 1-5r$)[15] and equals 1 when $w = 1 - 2.28r$; (ii) the RHS of (9) is strictly less than 1 and *decreasing* in w. It follows that given any positive probabilities of no entry and of unobservability of commitment, no matter how small, and given any value of the discount factor, no matter how close to 1, for every r there will be a value of w above which the introduction of

[13] In fact, the entrant's reaction curve will be given by a line above and parallel to RR' (corresponding to $N'N$) up to the point where output equals capacity S_2 and by RR' thereafter. Similarly, the incumbent's reaction curve will be given by $N'N$ up to V_1 and zero afterwards. The point Z_1 is given by $(3-3w+r)/(8B)$.

[14] In fact, $(M-H)/(M-D) = (7/8) + 2r^2/(1-w-r)^2$.

[15] As w increases from 0 to $1-5r$, $[C/(M-D)]$ decreases from a number less than 0.22 to 0. Thus when w is very small, only very low values of p and q will induce the incumbent to refrain from deterring entry.

(δ = 0.95 , p = 0.9 , q = 0.99)

r	w	C/(M-D) = RHS of (9) =
0.10	0.7671	0.898
0.15	0.6507	0.898
0.20	0.5343	0.898
0.25	0.4177	0.898
0.30	0.3011	0.898
0.35	0.1851	0.898
0.40	0.0680	0.898

Fig. 3. For any given r, if w is greater than the corresponding value in the second column, $[C/(M-D)]$ is greater than the RHS of (9) and, therefore, entry deterrence is not optimal.

uncertainty has the effect of inducing the incumbent to switch away from entry deterrence. Fig. 3 shows, for given values of r, the value of w at which the ratio $[C/(M-D)]$ equals the RHS of (9), in the case where p, q and δ are very close to 1. For higher values of w, deterrence will *not* be optimal, since the RHS of (9) becomes smaller than the LHS, while for lower values of w the opposite is true. Furthermore, since, for any given p, the RHS of (9) increases with δ and q, the higher the probability that commitment is not observed and/or the lower the discount factor, the less likely it is that a foresighted incumbent would choose to commit, ceteris paribus. Finally, it is worth repeating that $[C/(M-D)]$ is the ratio of the reduction in profits (from monopoly level) due to commitment to the reduction in profits due to entry. As fig. 3. shows, when entry is not certain and/or commitment is not observed with certainty, it is not longer sufficient that this ratio be less than 1 in order for entry deterrence to be optimal.

4. Conclusion

The standard approach to the study of strategic entry deterrence is based on the assumption that if the incumbent does not take any actions, entry will take place with certainty, while if he takes an appropriate action, entry will be deterred with certainty. We have relaxed this assumption by allowing for the possibility that the potential entrant may find alternative investments more attractive than entry and for the possibility that the incumbent's commitment may not be observed (or correctly assessed) by the potential entrant(s). We investigated the effects of these two forms of uncertainty in a simple model and showed, in a numerical example based on Dixit's (1980) model of investment in excess capacity, that even very small probabilities of no entry and of failure to observe commitment may be sufficient to eliminate the attractiveness of actions aimed at deterring entry.

The intuition behind our results is clear. When the probability of entry (in the case where the incumbent is passive) is less than one, the incumbent has to weigh an uncertain reduction in profits, due to entry, against a certain reduction in profits, due to commitment. Furthermore, when it is not certain that the commitment will be observed, entry-deterring actions become even less attractive, since there is now a positive probability that the potential entrant will make the mistake of entering the market and thereby impose a cost not only on himself but also on the incumbent.

The effects of uncertain entry ($p<1$) on the incumbent's decision whether to commit or be passive are somewhat similar to those associated with the presence of an entry lag. In the case where there is a time lag between the decision to enter and the appearance of the new firm (due, for example, to the period required to plan and construct production and distribution facilities), De Bondt (1976, 1977) found that the longer the entry lag, the less worthwhile is any sacrifice of current gains for the incumbent, that is, the less willing is the incumbent to take entry-deterring actions.

The model we used was rather simple. In a more complex model one could allow for the possibility that the (relative) profitability of entry may decrease over time (because of, say, increasing consumer loyalty to the incumbent, or learning which reduces the incumbent's costs over time, etc.) In this case the incumbent would be even less willing to commit, since the probability of entry would be decreasing over time.

Another possible extension is to make the probability that the incumbent's commitment is not observed a decreasing function of the number of unsuccessful entries. In this case it is conceivable that commitment would, ceteris paribus, become more attractive.

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