

# **DISCUSSION PAPERS IN ECONOMICS**

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# Demand Growth and Strategically Useful Idle Capacity

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## Abstract

This paper presents a capacity preemption game between an incumbent firm and a potential entrant. If entry occurs, then competition proceeds through Cournot quantity competition. My model, like those of (pro)-300 (Strateful)

# 1 Introduction

The idea that a firm might create productive capacity for the purpose of preempting a (potential) rival is hardly novel. Further, there is no lack of empirical evidence of firms maintaining a persistent stock of idle capacity.<sup>1</sup> However, the current body of theoretical models concerning preemptive capacity has not directly addressed the issues in Justice Hanford's decision on what has become the text book case on *preemptive idle capacity*, *Alcoa Aluminum*.<sup>2</sup> In his decision, Justice Hanford suggests that Alcoa "always anticipate increases in demand for ingot and be prepared to supply them." Further, he suggests that the rationale behind Alcoa's behavior was that there was "no more effective exclusion than progressively to embrace each new opportunity as it opened, and to face every newcomer with new capacity..."<sup>3</sup> This paper investigates Justice Hanford's assertion that the maintenance of idle capacity is an effective method of entry deterrence when demand growth is anticipated.

While Dixit (1980) and Bulow et. al. (1985) demonstrate that capacity can be an entry deterrent, they have tied the strategic

Consider capacity setting prior to a Bertrand-Edgeworth price setting game. Here, prices are strategic complements, and

e.g. Gilbert and Harris (1981).) However, part of the accusation leveled at Dupont involve the preemption of their rivals' capacity investment. In particular, Dupont built a plant in DeLisle Mississippi " despite the acknowledgment that the complete facility might have to be held in readiness for operation ... until market conditions have sufficiently improved."<sup>6</sup>

The formal model is a two period game of Cournot quantity competition with an incumbent and a potential entrant. Capacity is used as a commitment device through which the incumbent gains a first mover advantage. In the first period, the incumbent firm sets capacity before the potential entrant may do so. However, the incumbent maintains this advantage in the second period only if there is no entry in the first period. Otherwise, in the second period, the two firms set output simultaneously, without making any change to their capacity. That is, the value of a foothold is the negation of the incumbent's first mover advantage. This is modeled by removing the capacity choice from the post entry game. I find that a two period model behaves in many ways the same as a one period model. However, it is possible to establish that, given sufficient growth in demand, entry deterrence requires the presence of idle capacity. With linear demand, one can demonstrate the existence of cases in which entry deterrence with idle capacity is the subgame perfect equilibrium.

There have been previous temporal models with capacity choice. For example,

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<sup>6</sup>Dobson et. al. (1994, p. 166).

Spulber (1981) also examines a two period model. However, Spulber does not distinguish between first and second period capacity, and does not allow entry to occur in the first period. Hence, even if Spulber's model includes demand growth, it would not allow the type of behavior studied here. Gilbert and Harris (1984), Eaton and Lipsey (1980) and Reynolds (1987) all examine dynamic capacity games, but assume away the possibility of infinite capacity. Eaton and Lipsey (1979) consider a growing spatial market, and show that an incumbent will expand into new markets before entry occurs.<sup>7</sup> Reynolds (1986) performs simulations of the American aluminum industry after

sets capacity (if he enters,) and 3) firms in the market set output simultaneously at the intersection of their reaction functions.



capacity  $K$ . Let  $\underline{R}_t(\cdot) = R_t(\cdot, 0)$  and  $\bar{R}_t(\cdot) = R_t(\cdot, \infty)$ . A superscript  $i$  on any of these functions indicates that it is firm  $i$ 's reaction function.

My results depend upon Ware's (1984) analysis of a single period capacity setting game, so let us suppress the time subscripts for the moment. See Figure 1 for an illustration. Denote the (zero capacity) Cournot Nash equilibrium as the point  $N = (N^I, N^E)$  (throughout a superscript  $i = I, E$  denotes the projection onto  $q$ ) and denote the point where  $\bar{R}^I$  and  $\underline{R}^E$  intersect as  $V$ .<sup>10</sup> In the Dixit (1980) model, the Incumbent sets capacity so as to make his preferred point on  $\underline{R}^E$  between  $N$  and  $V$  the Nash equilibrium of the post entry output game. Presuming that both points are feasible, he chooses between accommodating entry at the Stackelberg point  $S$  and deterring entry by committing to the limit output. Ware (1984) modifies Dixit's model by allowing the (potential) Entrant to set capacity as well. At this point, the Entrant has the commitment opportunity, and sets his capacity to choose a point on  $R^I(\cdot, K^I)$  between the intersections with  $\underline{R}^{E0}$

R<sup>E</sup>.

second period capacity.

Let us recall that, in an entry equilibrium, there is no second period capacity choice, leaving firms with  $K_2 = K_1$ . Consequently, if both firms have  $K_1 \leq N_2$ , then  $N_2$  is the second period output. If one firm has  $K_1 > N_2$ , then that firm's first period capacity determines second period output. Of course, if entry does not take place in the first period, then the Incumbent maintains her advantage, and capacity is set in the second period.

Since adding another period to the game has not changed the fundamental role of capacity, some aspects of equilibria should remain qualitatively unchanged. Capacity should be built only if it has commitment value. The Incumbent's first mover advantage should, in equilibrium, leave the Entrant without a desire to use his capacity for commitment. That is, the Entrant, should he enter in the first period, should build only capacity he will use in the first period. And finally, the Incumbent should, at a minimum be able to guarantee himself the modified Stackelberg outcome,  $\hat{S}_1$ , in the first period.

**Proposition 1** *In an entry equilibrium, the Entrant's first period capacity is no greater than his first period output, and the Incumbent's first period capacity is equal to her output in either the first or second period.*

*In a deterrence equilibrium, if the Incumbent's first period capacity is greater than her first period output, then her capacity is greater than her second period Cournot Nash*

output.

In any equilibrium, the Incumbent's first period output is greater than or equal to the minimum of her first period monopoly and first period generalized Stackelberg output.

Proposition 1 implies that idle capacity can not occur in a *delayed entry equilibrium*. Let  $\underline{M}_t = (\underline{R}_t^I(0), 0)$ . The first term,  $\underline{M}_t^I$ , is monopoly output. Let  $\bar{M}_t = (\bar{R}_t^I(0), 0)$ .  $\bar{M}_t^I$  would be monopoly output if a firm had no marginal costs. Consider an outcome with delayed entry and idle first period capacity. If capacity is left idle in the first period, then  $K_1^I > \bar{M}_1^I$ . Since the Entrant wishes to enter in the second period, but not in the first, it must be the case that  $\pi_1^E(\tilde{S}_0) < K_1^I$ .

By the definition of  $\bar{M}_1^I$ , its capacity

$\hat{S}_1^I \leq q_1^I = K_1^I = q_2^I \leq \hat{S}_2^I$ .<sup>14</sup> Entrant outputs are at  $\underline{R}_t^E(K_1^I)$ .

We can now investigate the conditions under which i le capacity occurs in a deterrence equilibrium. Throughout what follows, Assumption G is maintained. The following five conditions must be satisfied: (1) It is possible to deter first period entry, but only if the Incumbent maintains i le capacity. (2) It is possible to deter entry in the second period. (3) The Incumbent prefers entry deterrence to being a Stackelberg leader, and (4) given that entry has not occurred in the first period, the Incumbent prefers to deter it in the second period as well. The first two of these conditions are statements about the Entrant's payoffs in different situations. They might be restated as (1')  $\pi_1^E(\tilde{S}_1) + \pi_2^E(W_2) \leq \bar{F} + 2F \leq \pi_1^E(W_1) + \pi_2^E(N_2)$ , and as (2')  $\pi_2^E(W_2) \leq \bar{F} + 2F$ .<sup>15</sup> Using the second inequality from (1'), one can transform (2') into  $F \leq [\pi_2^E(N_2) - \pi_2^E(W_2)] + \pi_1^E(W_1)$ . Since  $\pi_1^E(W_1) \equiv \pi_1^E(\tilde{S}_1)$ ,  $\pi_2^E(W_2) < \pi_2^E(N_2)$  and  $0 < [\pi_2^E(N_2) - \pi_2^E(W_2)] + \pi_1^E(W_1)$ , there are  $\bar{F}$ , and  $F$  such that conditions 1 and 2 hold. This yields:

**Proposition 3** *Under Assumption G, one can find levels of fixed and sunk costs (i.e.  $F$  and  $\bar{F}$ ) such that a deterrence equilibrium requires i le capacity.*

Observe that Proposition 3 is merely a statement that there are circumstances under which, if the Incumbent wishes to deter entry, then he must maintain i le capacity.

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<sup>14</sup>If  $S_t^I < W_t^I$  in both periods, then it follows that  $S_1^I < q_1^I = K_1^I = q_2^I < S_2^I$ .

<sup>15</sup>For the sake of clarity, condition (1') is sufficient, but stronger than necessary.

To demonstrate that such equilibria actually exist, one must show that the Incumbent prefers deterrence through finite capacity to being a Stackelberg leader. Because it is not so easy to compare the Incumbent's payoffs in different circumstances, some further structure must be imposed. For the remainder of the paper, linear demand is assumed.

**Assumption L** Demand is linear:  $P_t = a_t - b(q_t^E + q_t^I)$  with  $a_2 > a_1 > c$ .

There remains the problem that the payoffs for deterring entry depend upon the fixed and sunk costs. Hence in comparing payoffs, it is convenient to fix upon a particular case. Specifically, let us presume for now that  $K_1^I = \underline{M}_2^I$  is sufficient to deter entry in both periods. The task of finding values for  $F$  and  $\bar{F}$  which justify this presumption is addressed later. The first benefit from Assumption L is the ability to rule out type 2 Stackelberg leadership.

**Proposition 4** *Let Assumption L hold. If there exists  $K_1^I \leq \min\{\underline{M}_2^I, W_2^I\}$  which is sufficient to deter entry in both periods, then type 2 Stackelberg leadership never occurs in equilibrium.*

The intuition of Proposition 4 is that either the first period or the second period is in some sense more important. If the first period is more important, then the Incumbent prefers type 1 Stackelberg leadership to type 2. If the second period is more important, then the Incumbent prefers to deter entry, because by presumption, entry deterrence is not difficult. It now remains to show that there are cases in which the Incumbent prefers deterrence to type 1 Stackelberg leadership, for which the following assumption

is useful.

**Assumption D**  $(a_1)^2 + 2a_1c - (c)^2 \geq (a_2 - c)(5c - a_2)$ .

Sufficient conditions for Assumption D to hold are:  $\frac{a_1}{c} \geq 1.5$  or  $\frac{a_2}{c} \geq 4.5$ . Assumption D is an algebraic statement that the second period is more important than the first period, so that the Incumbent prefers deterrence, when it is relatively easy, to type 1 Stackelberg leadership.

**Proposition 5** *With linear demand,  $\pi_1^I(\bar{M}_1) + \pi_2^I(\underline{M}_2) - c(\underline{M}_2 - \bar{M}_1) \geq \pi_1^I(\hat{S}_1) + \pi_2^I(N_2)$  if and only if Assumption D holds.*

Proposition 5 is a statement that the Incumbent would be willing to hold the second period monopoly capacity,  $\underline{M}_2^I$ , in the first period to deter entry. Hence, while Assumption D is 'tight' for Proposition 5, there are clearly cases in which Assumption D does not hold, but the Incumbent is nonetheless willing to hold finite capacity. Likewise, if Assumption D holds with a strict inequality, then the Incumbent would be willing to hold capacity greater than  $\underline{M}_2^I$  to deter entry. However, this gives us an easy case to check for parameter values such that the Incumbent finds entry deterrence both possible and desirable.

Let us fix  $\Omega = (K^L, \underline{R}_2^E(K^L))$  for some capacity level  $K^L$ . Our task is complete by finding  $F$  and  $\bar{F}$  such that there exists  $K^L$ , with  $N_2^I < K^L \leq \hat{S}_2^I$ , satisfying the following two conditions. Entry deterrence is possible in the first period, if and only if the Incumbent maintains at least capacity  $K^L$ ;  $\pi_1^E(W_1) + \pi_2^E(\Omega) = \bar{F} + 2F <$



$$\pi_1^E(W_1) +$$

Less trivial would be to extend the model to a longer (possibly infinite) sequence of periods, allowing capacity setting in each period. Since a foothold is valuable in all future periods, an incumbent firm would have to consider eman in all future periods when choosing capacity. Reynolds (1987) has analyzed such a model for a duopoly market. He finds that concern over future periods increases the capacity which firms hold. This seems to indicate that results similar to those contained herein could be found in an infinite horizon model. However, Reynolds' analysis depends upon firm payoffs being quadratic in capacity, which disallows the possibility of infinite capacity.<sup>17</sup>

## 5 Appendix

The following four lemmas are for the purpose of proving Proposition 1.

**Lemma 5.1** *In an entry equilibrium, both firms set first period capacity less than or equal to first period output, or equal to second period output.*

*In a deterrence equilibrium, the Incumbent sets her capacity less than or equal to her first period output, or strictly greater than the second period Cournot output.*

Proof: We already know that capacity is not set above second period output, so it remains to rule out a choice of capacity greater than first period output, but less than second period output. In this case, the two firms' second period reaction functions must

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<sup>17</sup>Reynolds analyses a differential game within a continuous time framework.

cross at a point where the Incumbent produces more than his capacity. Since an increase in capacity will not alter this intersection, but will lower the Incumbent's first period costs, this can not be an equilibrium. ♣

**Lemm 5.** *In an entry equilibrium, if  $N_2^I \leq K_1^I$ , then the Entrant sets his capacity less than or equal to his first period output.*

Proof: If  $N_2^I \leq K_1^I \leq W_2^I$  then we know that the Entrant gets no benefit from capacity in the second period, because his optimal second period output

2) If  $K_1^E > W_1^I$  then  $K_1^I = \tilde{S}_1^E$  or  $K_1^I = \underline{R}_2(K_1^E) \geq \tilde{S}_1^E$

Proof: Let  $\bar{K}$  denote  $\underline{R}_1(K_1^E)$  for case 1 and  $\tilde{S}_1^E$  for case 2. Observe, that from Lemma 5.2 we know that  $\bar{K}$  would be an optimal response by the Incumbent if the Entrant moves first and chooses the capacity suggested in one of the cases. If the Incumbent has to choose some  $\underline{K} < \bar{K}$  in order to get the Entrant to choose  $K_1^E$ , then there is no equilibrium in which the Entrant chooses

at least as much profits in the first period, and strictly more profits in the second period than the Incumbent is making in equilibrium. Therefore the Entrant is making higher

$-2((a_2)^2 - 4a_2c - 5c^2)$  which itself follows with  $a_1 > c$  and  $a_2 > 7c$ . ♣

**Proof of Proposition 5**

$$\pi_1^I(\bar{M}_1) + \pi_2^I(\underline{M}_2) - c(\underline{M}_2 - \bar{M}_1) \geq \pi_1^I(\hat{S}_1) + \pi$$

$$W^E = \begin{cases} \frac{a-2c}{2b\sqrt{2}} & \text{if } a \leq 6c \\ \frac{\sqrt{a(a-3c)}}{3b} & \text{if } a \geq 6c \end{cases} \quad (7)$$

$$\hat{S} = (\min\{S^I, W^I\}, \max\{S^E, W^E\}) \quad (8)$$

$$\pi^E(\tilde{S}) = \pi^E(W) = \begin{cases} \frac{(a-2c)^2}{8b} & \text{if } a \leq 6c \\ \frac{a(a-3c)}{9b} & \text{if } a \geq 6c \end{cases} \quad (9)$$

$$\pi^I(\tilde{S}) = \begin{cases} \frac{a^2-4c^2}{16b} & \text{if } a \leq 6c \\ \frac{a(a-3c)}{9b} & \text{if } a \geq 6c \end{cases} \quad (10)$$

$$\pi^I(W) = \begin{cases} \frac{(a-2c)(a+c\sqrt{2})}{8b} \cdot (2\sqrt{2}-2) & \text{if } a \leq 6c \\ \frac{(a-c)\sqrt{a(a-3c)}}{3b} - \frac{2a(a-3c)}{9b} & \text{if } a \geq 6c \end{cases} \quad (11)$$

In the linear model,  $R_t(\cdot, K)$  is defined as follows.

$$R_t(q, K) = \begin{cases} \frac{a_t - bq}{2b} & \text{if } q < \frac{a_t - 2bK}{b} \\ \frac{a_t - bq - c}{2b} & \text{if } q > \frac{a_t - 2bK - c}{b} \\ K & \text{otherwise} \end{cases} \quad (12)$$

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