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Demand Growth and Strategically Useful Idle Capacity

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## **Abstract**

This paper presents a model

## 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 Hanlon's decision on what has become the text book case on *preemptive idle capacity*, *Alcoa Aluminum*.<sup>2</sup> In his decision, Justice Hanlon suggests that Alcoa is "always an

that idle capacity might arise if capacity is only one of the entry deterrence instruments available to the incumbent.<sup>5</sup> However, these models work with only a single period, and so assume away the possibility of demand growth. Consequently, the relationship between demand growth and strategically useful idle capacity suggested by Justice Hand can not be present. In this paper, I show that in the face of growing demand, entry deterrence may necessitate the maintenance of idle capacity. This result requires neither strategic complements, nor the presence of additional deterrence instruments. Rather, it follows from an entrant's willingness to take early losses in order to gain a foothold in a market and make profits in later stages. Knowing the value of a foothold, the incumbent firm recognizes that deterrence requires sufficient capacity to make both the current and future periods unprofitable for the potential entrant. If demand is growing, then this might require maintaining idle capacity.

Beyond the Alcoa Case, these arguments shed some light on the case of Dupont's alleged attempts to achieve and maintain market dominance in titanium dioxide. Dupont's advantage was based upon lower costs from learning by doing (see e.g. Gilbert and Harris (1981).) However, part of the accusation leveled at Dupont involves the preemption of their rival's capacity investment. In particular, Dupont built a plant in DeLisle Mississippi " despite the acknowledgment that the complete facility might

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Tirole (1983), Akerlof (1979), Schmalensee (1981), and Spence (1979).

<sup>5</sup>Basu and Singh (1990) use a *Stackelberg perfect* equilibrium to capture the commitment value of the Incumbent's other instruments.

have to be held in readiness for operation ... until market conditions have sufficiently improved.”<sup>6</sup> Hence, my analysis sheds light on at least a portion of Dupont’s behavior.

The formal model is a two period game with an incumbent and a potential entrant. In both periods, firms have an opportunity to build additional capacity, after which they engage in Cournot quantity competition. In the first period, the incumbent firm sets capacity before the potential entrant may do so. However, the incumbent maintains this first mover advantage in the second period only if there is no entry in the first period. Otherwise the two firms set second period capacity simultaneously. That is, the value of a toehold is modeled as the negation of the incumbent’s first mover advantage. 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 a subgame perfect equilibrium.

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

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

the possibility of idle 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 the Alcoa decision, and finds that a dominant firm model (Kylasan, 1977) does the best job of replicating the persistent idle capacity in that market.<sup>8</sup>

The remainder of the paper is organized as follows: the model is presented in Section 2, and analyzed in Section 3. Section 4 concludes. Many proofs are contained in the appendix.

## 2 Model

The model presumes that an incumbent firm has a first mover advantage only until the entrant establishes a foothold in the industry. The timing of the model in period one is: 1) the incumbent ( $I$ ) sets capacity. 2) The entrant ( $E$ ) makes his entry decision, and sets capacity (if he enters,) and 3) firms in the market set output simultaneously at the intersection of their reaction functions.<sup>9</sup> If there is still only a single firm in the market at the beginning of the second period, then the timing in the second period mimics that in the first. However, if there was entry in period one, then in the second period firms

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<sup>7</sup>Eaton and Lipsey suggest that there is *excess* capacity in the industry.

set (increases) capacity simultaneously after which they simultaneously set output.

Throughout, subscripts will denote time periods,  $t = 1, 2$ , and superscripts will denote either players  $i = I, E$  or special outcomes. For example,  $q_t$  refers to firm  $i$ 's output in period  $t$ . In period  $t$ , for an aggregate output  $Q$ , prices are determined by an inverse demand  $P_t(Q)$ . Demand in both periods is assumed to satisfy:  $P_t' + P_t'' \cdot Q > 0$ . Demand growth is formalized by requiring that  $P_2(Q) > P_1(Q)$  and that  $|P_2'| \leq |P_1'|$  for all aggregate outputs  $Q$ . This is satisfied, for example, with linear demands:  $P_t = a_t - bQ$  with  $a_2 > a_1$ . These assumptions guaran



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 dominant firm 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  $\underline{R}^E$  (pl(Nf8n8.0002-6ah)8002(20001207d10(I

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capacity. In the current analysis, it is not a priori clear which firm will set the largest capacity. In fact, as Proposition 8 (Appendix) demonstrates, there are a continuum of second period equilibrium continuations following first period entry. In particular, consider the outcome if the incumbent (resp. entrant) has a first mover advantage in the second period. If both firms anticipate this outcome, then they are both choosing a best response. Hence, an outcome in which either of the firms has the ability to commit to his second period capacity is an equilibrium when the firms choose simultaneously. Further there is a full range of equilibria 'in between' these two cases which might be thought to correspond to intermediate distributions of commitment power. I make the following assumption to avoid multiplicity of equilibria.

**Assumption E** In an entry equilibrium: 1)  $q_2 = \Omega$  for  $i = I, E$ ,

2)  $K_1^E \geq q_1^E$ .

Part 2 of Assumption E is innocuous, and merely serves to make the statement of Propositions easier.<sup>13</sup> Under Assumption E1, output in both periods of an entry equilibrium is determined by the first period capacity choice. 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 (and the other firm's reaction function) determine second period capacity. That is, second period output is chosen as if there were no second period capacity decision.<sup>14</sup> This reflects the idea that capacity is a commitment device,

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<sup>13</sup> See Proposition 9 in the Appendix.

<sup>14</sup>The ability to set capacity in the second still plays a role, in that it limits the incumbent's ability

and once entry occurs, the incumbent has lost his first mover advantage, and hence his commitment advantage. In Section 4, I argue that Assumption E Part 1 rules out implausible equilibria, and captures the desirable aspects of a forward induction argument (as in Bagwell and Ramey, 1996.)

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 only be built if it has commitment value, in either the first or second period. 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 monopoly Stackelberg outcome,  $\hat{S}_1$



incumbent's first period capacity to have a consequence in the second period, it must be greater than  $N^I$

period, and can commit to an output in the second period. In this case, the incumbent chooses  $K_1^I$  such that  $\hat{S}_1^I \leq q_1^I = K_1^I = q_2^I \leq \hat{S}_2^I$ .<sup>17</sup> Entrant outputs are at  $\underline{R}_t^E(K_1^I)$ .

We are now ready to turn to the paper's central issue, under what conditions can idle capacity occur in 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 2) only if the incumbent maintains idle capacity. 3) It is possible to deter entry in the second period. 4) The incumbent prefers entry deterrence to being a Stackelberg leader, and 5) given that entry has not occurred in the first period, the incumbent prefers to deter it in the second period as well. The first three of these conditions are statements about the Entrant's payoffs in different situations. They might be restated as 1')  $\pi_1^E(\tilde{S}_1) + \pi_2^E(W_2) \leq \bar{F} + 2F$ , 2')  $\pi_1^E(W_1) + \pi_2^E(N_2) \geq \bar{F} + 2F$ , and 3')  $\pi_2^E(W_2) \leq \bar{F} + 2F$ . These conditions can be translated to  $\pi_1^E(\tilde{S}_1) + \pi_2^E(W_2) \leq \bar{F} + 2F \leq \pi_1^E(W_1) + \pi_2^E(N_2)$  and  $F \leq [\pi_2^E(N_2) - \pi_2^E(W_2)] + \pi_1^E(W_1)$ . Since  $\pi_1^E(W_1) \equiv \pi_1^E(\tilde{S}_1)$ ,  $\pi_2^E(W_2) < \pi_2^E(N_2)$  and  $0 < [\pi_2^E(N_2) - \pi_2^E(W_2)] + \pi_1^E(W_1)$ , one can choose  $\bar{F}$ , and  $F$  such that conditions 1, 2 and 3 hold. This yields:

**Proposition 4** *Under Assumption G, one can find values for  $F$  and  $\bar{F}$  such that a deterrence equilibrium requires idle first period capacity.*

Observe that Proposition 4 is merely a statement that there are circumstances under which, if the incumbent wishes to deter entry, then he must maintain idle capacity. To

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<sup>17</sup>If  $S_t^I < W_t^I$  in both periods, then it follows that  $S_1^I < q_1^I = K_1^I = q_2^I < S_2^I$ .

emonstrate that such equilibria actually exist, one must show that the entrant prefers eterence through i le capacity over being a Stackelberg leader. Because it is not so straight forward to compare the incumbent's payoffs in i fferent circumstances, some further structure must be impose . For the remain er of the paper, linear eman is assume .

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

There still remains the problem that the payoffs for etering entry epen crucially upon fixe costs. Hence in comparing payoffs, it is convenient to fix upon a particular case. Specifically, let us presume for now



reference to type 1 Stack

in the first period, if an entrant only if the incumbent maintains at least capacity  $K^L$ . Since  $K^L > N_2^I$ , and Assumption G holds, this involves a finite capacity.  $\pi_2^E(\hat{S}_2) \leq \bar{F} + F$  assures that deterrence in the second period is feasible, an entrant never requires more than the monopoly level of capacity. Hence, a delay in

ments for entry reference. Consequently,

Another possibility would be to select equilibria through a forward induction argument (as in Bagwell and Ramey, 1996.) In this case, because there are multiple equilibrium continuations in the second period, the entrant has a second mover advantage. That is, forward induction requires that if entry occurs in the first period, then the entrant must be planning a continuation in the second period that would yield him positive profits. Clearly for entry deterrence to be forward induction rational requires that there be no continuations which yield the entrant positive profits. Since the entrant's most preferred continuation is when the incumbent does not increase her capacity, the requirements for deterrence would remain unchanged. However, the entrant's second mover advantage might have a dramatic consequence in entry equilibria. For example, it might be the only continuations which give the entrant positive profits are those in which the entrant acts as a Stackelberg leader in the second period. This would clearly make a toehold in the industry worth more than a simple negation of the incumbent's first mover advantage. On the other hand, because there are many cases in which many equilibria would survive forward induction, the question of selection would remain.

## 5 Appendix

### Proof of Proposition 1

If  $K_1 > \Omega$  then  $K_2 \geq K_1 > \Omega \geq q_2$  since the only thing that can move second period output away from  $\Omega$  is if firm  $j \neq i$  increases capacity which will weakly decrease firm

$i$ 's equilibrium output. Also the only way that  $\Omega > W_2^I$  is if  $K_1 > W_2^I$ , which implies  $K_2 > W_2^I$  and  $K_2^j = \tilde{S}_2^E$  and firm  $i$  will be left with  $K_2 > q_2$ . Since we know that  $K_2 \leq q_2$  the Proposition follows. ♣

**Proposition 8** *Presume entry  $n$  per od one, and fix per od one capacities such that they satisfy Proposition 1. A choice of second per od capacities and outputs are a second per od equilibrium if and only if  $K_1 \leq K_2 \leq W_2^I$  ( $i = I, E$ ) and one of the following conditions holds.*

- 1)  $K_2^I \geq K_2^E$ )  $q_2^I = K_2^I = S_2^I$  and  $K_2^E \leq q_2^E = \hat{S}_2^E$
- 2)  $K_2^I \geq K_2^E$ )  $N_2^I \leq q_2^I = K_2^I \leq S_2^I$  and  $K_2^E = q_2^E = \underline{R}_2^E(K_2^I)$
- 3)  $K_2^I \leq K_2^E$ )  $q_2^E = K_2^E = S_2^I$  and  $K_2^I \leq q_2^I = \hat{S}_2^I$
- 4)  $K_2^I \leq K_2^E$ )  $N_2^E \leq q_2^E = K_2^E \leq S_2^I$  and  $K_2^I = q_2^I = \underline{R}_2^I(K_2^E)$

Proof: Assume without loss of generality  $K_1 \leq W_2^I$  (of)]TJΩ(8204980TDΩ(K)TjΩT71TfΩ84.0002-33TDΩ(I)TjΩ

**Proposition 9** *Let Assumption E1 hold. If there is an entry equilibrium in which  $q_1^E > K_1^E$ , then there is another equilibrium in which all outputs are unchanged, firms receive the same profits, and  $q_1^E = K_1^E$ .*

Proof: That  $K_1^E < q_1^E$  implies that first period output is on  $\underline{R}_1^E$  and that  $q_1^E \leq N_1^E$ . Hence increasing  $K_1^E$  to  $q_1^E$  will not change the intersection of first period reaction functions, nor will it result in  $K_1^E > N_2^E$ . Hence, the output in neither period will change. Since capacity is only a commitment to pay costs that must be paid if production takes place, and outputs have not c

implies that capacity less than the second period Cournot has no consequence in the second period. ♣

**Lemm 5.** *Let Assumpt on E Part 1 hold. In an entry equilibrium, if  $N_2^I \leq K_1^I \leq W_2^I$ , 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 is (holding  $K_2^I = K_1^I$ )  $\underline{R}_2(K_1^I)$  which he will receive even if  $K_1^E = 0$  (Assumption E1) Hence he sets  $K_1^E \leq q_1^E$ . ♣

The point of the following two Lemmas is to rule out the case where the dominant firm wishes to act like a Stackelberg follower in the second period, and hence chooses a low capacity to induce the entrant to choose a 'leader' capacity. Hence in these proofs there is a possibility that the dominant firm sets his capacity at say  $\tilde{S}_1^E$ .

**Lemm 5.3** *Let Assumpt on E Part 1 hold. Presume that there is an entry equilibrium in which the incumbent chooses  $K_1^I < N_2^I$ , but the entrant chooses  $K_1^E > N_2^I$ .*

1) *If  $K_1^E \leq W_1^I$  then  $K_1^I \leq \underline{R}_1(K_1^E)$  or  $K_1^I = \underline{R}_2(K_1^E) > \underline{R}_1(K_1^E)$ .*

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 the optimal response by the incumbent if the entrant move first and chose 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







## 6 Linear Appendix

I provide here algebraic expressions for the values defined in section 2. Since these are based upon the one period model, I drop the time subscript. When I mention points in  $q^I, q^E$  space, the  $q^I$  value is listed first.

$$N = \left( \frac{a-c}{3b}, \frac{a-c}{3b} \right) \quad (1)$$

$$V = \left( \frac{a+c}{3b}, \frac{a-2c}{3b} \right) \quad (2)$$

$$U = \left( \frac{a}{3b}, \frac{a}{3b} \right) \quad (3)$$

$$S = \left( \frac{a-c}{2b}, \frac{a-c}{4b} \right) \quad (4)$$

$$\tilde{S} = \begin{cases} \left( \frac{a+2c}{4b}, \frac{a-2c}{2b} \right) & \text{if } a \leq 6c \\ U & \text{if } a \geq 6c \end{cases} \quad (5)$$

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

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

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

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

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

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