Strategic Excess Capacity and First-Mover Advantage under Variable Demand

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This paper modifies Spulber's (1981) two-period model of entry-deterrence game by introducing variable demand. I show that the incumbent firm may hold pre-entry excess capacity under the post-entry game rule of Cournot-Nash, if post-entry demand is greater enough than pre-entry demand. The Excess Capacity Hypothesis is thus revived. It is also shown that if the discount rate is sufficiently high under a booming prospect of the market, the incumbent may choose to give up its first-mover advantage by installing extra capacity in the post-entry phase. A numerical example with implications for antitrust policy is also presented. (*JEL* Classifications: D43, L13, L41)

I. Introduction

In modeling entry deterrence games between an established firm and a prospective entrant under complete information (usually treated before Milgrom and Roberts' (1982) model under incomplete information), the Sylos Postulate and the Excess Capacity Hypothesis used to be the main behavioral assumptions as to how the established firm would employ pre-entry choice variables as a means to deter entry or to alter the initial conditions of the post-entry game to the advantage of the established firm. The Sylos Postulate states that an established firm deters entry by keeping a constant high output. This assumption was dropped afterwards notably after Spence' (1977) article where he criticized that it is irrational for the incumbent to keep its output at an

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entry-deterring level regardless of whether or not it is profitable to do so. He made an alternative assumption (the Excess Capacity Hypothesis) that the entrant would base its entry decision on the established firm's pre-entry capacity, and then he constrained the established firm to choose capacity at or above the entry-deterring level, irrespective of its profitability.

The post-entry game in Spence' model is of a Stackelberg type with the established firm, as the leader, making a commitment to the output level equal to its pre-entry capacity. According to Dixit (1980), however, if the post-entry game is Cournot-Nash, the established firm would not wish to install capacity that would be left idle in the pre-entry stage. This result is due to the argument that the irrevocable (or sunk) investment in capital prior to new entry enables, in the post-entry phase, the established firm to ignore the (sunk) capacity cost the entrant does have to consider, and thus that the established firm can exercise leadership, though over a limited range, by using its capacity choice to manipulate the initial conditions of the post-entry game.

But Dixit's model is static in that there is no consideration of time preference and that the established firm installs capacity without any production in pre-entry phase. Extending Dixit's model into a two-period framework in which the established firm is engaged in production in each period, Spulber (1981) shows that if the post-entry game is Cournot-Nash, the incumbent firm never holds excess capacity in the first period whether or not it allows entry. Spulber's model is based on the assumption that market demand remains invariant over time and that the established firm's commitment to capacity is made in the first period so that it is unable to increase its capacity even if it wishes to build additional capacity in the second period. Market demand, however, varies over time in reality, and new entry is more likely to occur when the market is anticipated to grow in the future. Moreover, the incumbent firm can expand capacity at its will after new entry.

Relaxing Spulber's assumptions and thus dealing with the more realistic case in which demand varies over time and additional capacity installment is possible, this paper shows that the incumbent firm may hold excess capacity in the pre-entry stage even under the post-entry game rule of Cournot-Nash, if market demand in the future is greater enough than the current demand. The Excess Capacity Hypothesis is revived consequently.[1] It is also shown that if the discount rate is suffi-

[1]Perrakis and Warskett (1983), using Spulber's (1981) model as well, argue

ciently high under a booming prospect of the market, the incumbent may choose to give up its first-mover advantage (*i.e.*, a cost leadership gained by no need to pay capacity cost in the second period) by delaying installation of some capacity until the post-entry phase and thus competing on an equal footing with the new entrant.

The intuition of the results of this paper is as follows. When market demand remains constant over time, the established firm's production capacity at its monopoly days is likely to be more than sufficient to meet the output needed for the equilibrium of the post-entry game. The established firm naturally finds itself owning the first-mover advantage of not having to pay capacity cost. When future demand is high enough, however, the current monopoly output is likely to fall short of the output needed to fulfill the post-entry equilibrium. So the incumbent must decide whether to install the additional capacity now or after new entry occurs. If the discount rate is not that high, holding excess capacity now costs the incumbent little but confers upon it a cost advantage over its rival in the post-entry stage. If the discount rate is sufficiently high, however, the incumbent may be better off renouncing its first-mover advantage by delaying capacity installment until the post-entry phase and competing on even terms with the new entrant.

This paper thus modifies the received conclusion that the Excess Capacity Hypothesis is inconsistent with the post-entry game rule of Cournot-Nash, and presents the new result that an established firm's first-mover advantage is a matter of choice, not a predetermined condition.

Since pre-entry excess capacity can occur in the model of this paper, it is possible to examine the welfare effect of antitrust action (occasionally attempted by antitrust authorities) against the established firm's strategic capacity expansion. It turns out, through a numerical exam-

that the Excess Capacity Hypothesis is valid under the Cournot-Nash post-entry game if demand uncertainty is introduced. In their paper, however, the occurrence of excess capacity in the pre-entry period is merely a result of the separation of capacity and output decisions within each period. This separation is due to the assumption that demand is random and that it is realized between a capacity choice and a production activity. Then, the established firm, even without entry threat, may end up holding capacity in excess of the optimal output level if the random demand is realized at a low value and capacity cost is low. Therefore, the excess capacity observed in their paper has intrinsically nothing to do with an intention to exercise a cost advantage over the new entrant.

ple, that such an action may reduce welfare to the contrary of its original goal of fostering competition, and thus cannot be justified. Restraining excess capacity held by the incumbent renders a favor to the entrant, but reduces consumer's surplus as well as the incumbent's rent. This result confirms Spulber's (1989) advice against antitrust action restricting strategic excess capacity. His policy advice, however, is based upon his conclusion that excess capacity cannot occur under the post-entry game rule of Cournot-Nash.

The paper is organized as follows. In Section II, the model of the paper is described. In Section III, the main result of this paper is derived. Section IV presents a numerical example and its implications. Section V concludes the paper.

II. The Model

We consider a two-period model in which a single established firm, called 'firm A', installs capacity and produces output in both the first and second periods, and another firm, called 'firm B', installs capacity and produces output in the second period only. The second-period game between firm A and firm B is assumed Cournot-Nash. One of the main features of this paper is that firm A can install additional capacity in the second period if it wishes to do so, in contrast with Spulber (1981).[2]

Following Dixit (1980) and Spulber (1981), it is assumed that the firm's capital expenditures, once made, become irreversible or sunk in that they have no intrinsic value to other firms, cannot be allocated to another use within the firm, and therefore have no value on a second-hand market. This is the very assumption that distinguishes Dixit's paper from its predecessors and makes it possible for the established firm to command a cost advantage in the post-entry period by not having to consider capacity installment costs.

Let q_1^A and q_2^A denote firm A's output in the first and second periods, respectively, and let q^B denote firm B's output. Each period, firm A installs capacity k_1^A, k_2^A at unit cost z. Firm B's capacity is denoted by k^B and its unit cost is also z. Let $c^A(\cdot)$ and $c^B(\cdot)$ represent the two firms' variable cost functions in each period. Assume that $c^j(\cdot)(j = A, B)$ is twice continuously differentiable, increasing, and convex with $c^j(0) = 0$.

[2]Dixit (1980) also allows the incumbent firm to expand capacity after entry, but his model is static in that there is no production activity before entry.

Let $p_1(\cdot)$ and $p_2(\cdot)$ denote the first and second periods' inverse demand functions, each of which is assumed decreasing, twice continuously differentiable, and concave. We make additional assumptions on $p_2(\cdot)$ to ensure the existence of an equilibrium of the second-period game: $p_2(0) < \infty$, $p_2(\cdot) > 0$ over $[0, \overline{Q})$ for a certain number $\overline{Q} < \infty$, $p_2(\cdot) = 0$ over $[\overline{Q}, \infty)$.[3]

III. The Equilibrium of the Game

A. The Cournot-Nash Equilibrium in the Second Period

We consider the entrant's problem first. Since the entrant stays in the market only for a single period, its output and capacity are identical, *i.e.* $q^B = k^B$. Thus, the entrant must choose its output q^B to maximize its profit net of capacity cost zq^B, given the second period output of firm A, q_2^A. Then, the entrant's reaction curve which we denote by $q^B = \gamma^B(q_2^A)$(RR' in Figure 1) is derived by the following 'marginal revenue = marginal cost' equation.

$$\frac{\partial}{\partial q^B}\{p_2(q_2^A + q^B)q^B\} = c^{B\prime}(q^B) + z. \tag{1}$$

Now we consider the established firm's problem backwards from the second period. In the second period, it must choose its output q_2^A given the entrant's output q^B to maximize its profit net of capacity cost. Its capacity cost is zero if $q_2^A \leq k_1^A$ or $z(q_2^A - k_1^A)$ if $q_2^A > k_1^A$, because the established firm is allowed in the second period to install additional capacity at unit cost z.[4] Given the value of k_1^A, the established firm's reaction curve which we denote by $q_2^A = \gamma^A(q^B; k_1^A)$ is then derived from the following 'marginal revenue = marginal cost' equations:

$$\frac{\partial}{\partial q_2^A}\{p_2(q_2^A + q^B)q_2^A\} = c^{A\prime}(q_2^A) \quad \text{if} \quad q_2^A \leq k_1^A, \tag{2}$$

$$\frac{\partial}{\partial q_2^A}\{p_2(q_2^A + q^B)q_2^A\} = c^{A\prime}(q_2^A) + z \quad \text{if} \quad q_2^A > k_1^A. \tag{3}$$

Let $q_2^A = \gamma_-^A(q^B)$ and $q_2^A = \gamma_+^A(q^B)$ be solutions to (2) and (3), respectively, with "if" parts ignored.[5] Then, in (q_2^A, q^B) plane, firm A's reaction curve $q_2^A = \gamma^A(q^B; k_1^A)$(= $N'xyM$ in Figure 1) is a combination of $q_2^A = \gamma_-^A(q^B)$(= $N'N$)

[3]Under these assumptions, there exists a unique Cournot equilibrium of the second-period game. See Friedman (1982).

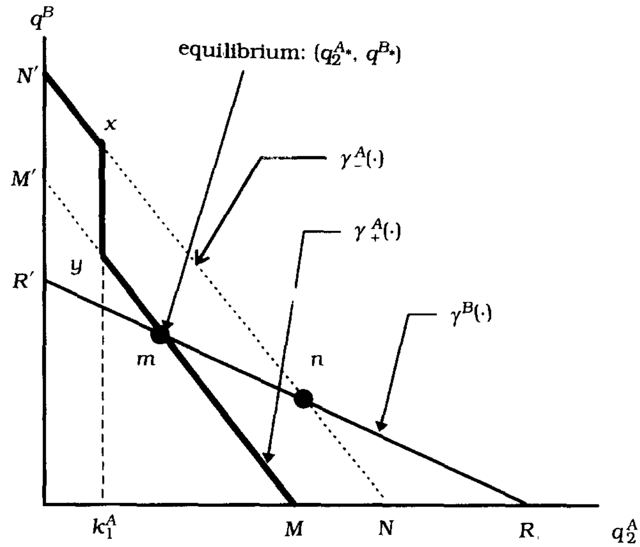

Figure 1
Type 1 Equilibrium

(to the left of the vertical line $q_2^A = k_1^A$) and $q_2^A = \gamma_+^A(q^B)(= M'M)$(to the right of $q_2^A = k_1^A$). Let M^A, N^A, R^A denote the q_2^A-coordinates of points M, N, and R, and let M^B, N^B, and R^B denote the q^B-coordinates of points M', N', and R' in Figure 1, respectively. We suppose that $N^A < R^A$ and $R^B < M^B$, so $q^B = \gamma^B(q_2^A)$ intersects with both $q_2^A = \gamma_+^A(q^B)$ and $q_2^A = \gamma_-^A(q^B)$. Note that if NN' and RR' do not intersect and $k_1^A > R^A$, then entry is blockaded and the first-period capacity is fully utilized. Moreover, entry will be deterred if the entrant's profit is negative on the equilibrium point whereas the established firm's profit is positive. Since entry deterrence itself is not the subject of this paper, we simply assume that both firms' second-period profits are non-negative on the intersection points of their reaction curves.[6]

[4]It is because capacity investment is assumed sunk that the established firm does not have to consider capacity cost when the second-period output is less than the first-period capacity.

[5]The "−" sign in subscript sig... ...hat there is no additional capacity installation, and "+" means the opposite.

[6]The classical industrial organization literature is mainly concerned with the issue of whether and how a dominant firm actually forces rivals out of the mar-

Let the two intersection points be referred to as m and n in Figures 1 through 3, and let m^A and n^A (m^B and n^B) denote the $q_2^A(q^B)$-coordinates of m and n, respectively.

Then, depending on the position of k_1^A relative to m^A and n^A, the equilibrium of the post-entry game can be categorized into three types as depicted in the Figures 1-3.

Let $V(k)$ denote the established firm's second-period profit evaluated at the equilibrium that prevails when its first-period capacity is given as k, and $V'(k)$ denote its marginal profit. We now derive $V(k)$ for each type of the second-period equilibrium.

Type 1. $k < m^A \Rightarrow$ Additional capacity is installed.

Since the equilibrium is reached at point m and k falls short of the m^A, additional capacity is installed by as much as $m^A - k$. Therefore,

$$V(k) = p_2(m^A + m^B)m^A - c^A(m^A) - z(m^A - k), \tag{4}$$

$$V'(k) = z. \tag{5}$$

Type 2. $m^A \leq k \leq n^A \Rightarrow$ The first-period capacity is fully utilized.

Since the equilibrium is reached at $(k, \gamma^B(k))$, there is no additional capacity installation. Therefore,

$$V(k) = p_2\{k + \gamma^B(k)\}k - c^A(k), \tag{6}$$

$$\begin{aligned} V'(k) = {} & p_2'\{k + \gamma^B(k)\}k + p_2\{k + \gamma^B(k)\}k - c^{A\prime}(k) \\ & + p_2'\{k + \gamma^B(k)\}k\gamma^{B\prime}(k). \end{aligned} \tag{7}$$

The first two terms of the right-hand side of (7) are marginal revenue evaluated at point m. Since m and n are points on $q_2^A = \gamma_+^A(q^B)$ and $q_2^A = \gamma_-^A(q^B)$, respectively, marginal revenue at m^A must equal $c^{A\prime}(m^A) + z$, whereas marginal revenue at n^A must equal $c^{A\prime}(m^A)$. Thus, we obtain expressions for $V'(m^A)$ (the derivative from the right) and $V'(n^A)$ (the derivative from the left) as follows:

$$\begin{aligned} V'(m^A) &= \text{marginal revenue at } m^A - c^{A\prime}(m^A) - z + z \\ &\quad + p_2'\{m^A + \gamma^B(m^A)\}m^A\gamma^{B\prime}(m^A) \\ &= 0 + z + p_2'\{m^A + \gamma^B(m^A)\}m^A\gamma^{B\prime}(m^A) \end{aligned} \tag{8}$$

ket just because it is an incumbent. This paper, however, rules out the 'no-entry' case and is focused on whether and how the incumbent firm possesses a cost advantage over the rival through holding excess capacity in the pre-entry phase.

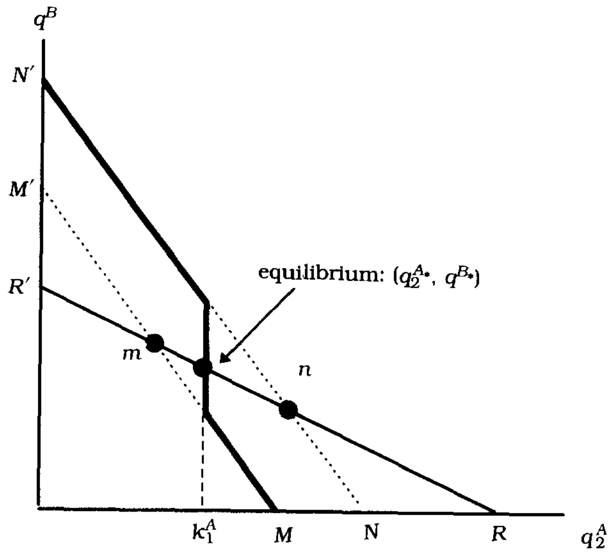

FIGURE 2
TYPE 2 EQUILIBRIUM

$$= z + p_2'\{m^A + \gamma^B(m^A)\}m^A\gamma^{B\prime}(m^A).$$

$$\begin{aligned} V'(n^A) &= \text{marginal revenue at } n^A - c^{A\prime}(n^A) + p_2'\{n^A + \gamma^B(n^A)\}n^A\gamma^{B\prime}(n^A) \\ &= 0 + p_2'\{n^A + \gamma^B(n^A)\}n^A\gamma^{B\prime}(n^A) \\ &= p_2'\{n^A + \gamma^B(n^A)\}n^A\gamma^{B\prime}(n^A). \end{aligned} \tag{9}$$

Since $p_2'(\cdot) < 0$, and $\gamma^{B\prime}(\cdot) < 0$ from (1), we have

$$V'(m^A) > z. \tag{10}$$

Type 3. $k > n^A \Rightarrow$ Capacity is left idle.

The equilibrium is reached at point n and $k > n^A$, so capacity is left idle by as much as $k - n^A$. Therefore,

$$V(k) = p_2(n^A + n^B)n^A - c^A(n^A), \tag{11}$$

$$V'(k) = 0. \tag{12}$$

B. The First-Period Problem of the Established Firm

We now turn to the established firm's capacity and output decision in the first period. Define $\pi(q) \equiv p_1(q)q - c^A(q)$ (the established firm's first-period profit with capacity cost excluded) and $\mu \equiv \arg\max \pi(q)$.

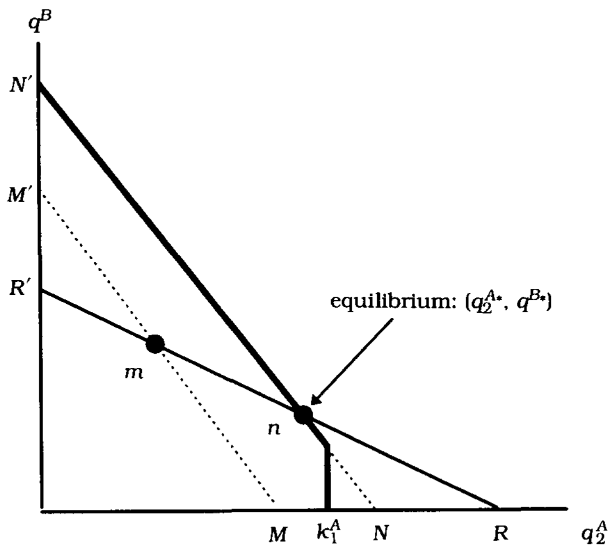

FIGURE 3
TYPE 3 EQUILIBRIUM

Then, given the discount (or interest) rate r, its optimization problem is:

$$\begin{aligned} &\operatorname*{Max}_{q,k}\ \{\pi(q) - zk + (1 + r)^{-1}V(k)\} \\ &\text{s.t.}\ \ q \leq k. \end{aligned} \tag{13}$$

Note that though V is not necessarily concave over $[m^A, n^A]$ from (6), there exists a solution to the optimization program (13) because the objective function is continuous and k^*, if it exists, is at most $\max\{\mu, n^A\}$, implying that (13) is equivalent to a modified optimization problem with k subject to being within the compact set $[0, \max\{\mu, n^A\}]$.[7]

Denoting the Lagrange multiplier for the constraint of (13) by λ and the solution to (13) by (q^*, k^*, λ^*) where $k^* \neq m^A, n^A$, the Kuhn-Tucker first-order conditions for optimization are as follows:

$$\pi'(q^*) = \lambda^*, \tag{14}$$

$$\lambda^* + (1 + r)^{-1}V'(k^*) = z, \tag{15}$$

$$\lambda^*(k^* - q^*) = 0,\ \lambda^* \geq 0, \tag{16}$$

[7]Otherwise, the established firm holds excess capacity at both periods, which cannot be optimal.

$$k^* - q^* \geq 0. \tag{17}$$

Note from the analysis in the previous subsection that V is differentiable except at m^A and n^A. Therefore, equation (15) is satisfied when $k^* \neq m^A$, n^A. If $k^* = m^A$ or n^A, (15) will be altered to

$$\lambda^* + (1 + r)^{-1}V'(k^* - \varepsilon) \geq z \text{ and } \lambda^* + (1 + r)^{-1}V'(k^* + \varepsilon) \leq z \quad \text{for a sufficiently small } \varepsilon > 0. \tag{15}'$$

From the above conditions, we can derive the following proposition that consists of three parts corresponding to the three cases; $\mu < m^A$, $m^A \leq \mu \leq n^A$, and $\mu > n^A$. As the future market demand grows, the values of m^A and n^A are likely to be greater than μ.[8]

Proposition 1

I. If the market demand of the second period is great enough so that $\mu < m^A$, then the following statements are true.

(i) If r is sufficiently small, excess capacity occurs in the pre-entry phase. The post-entry equilibrium is of type 2 with $q^* = \mu < m^A < k^* \leq n^A$.

(ii) If r is sufficiently large, the established firm holds no excess capacity in the pre-entry phase and builds additional cpacity in the post-entry phase as the post-entry equilibrium is of type 1 with $q^* = k^* \leq \mu < m^A$.

II. If $m^A \leq \mu \leq n^A$, then the following statements are true.

(i) If r is sufficiently small,

a. The post-entry equilibrium is of type 2 with $m^A \leq k^* \leq n^A$.

b. Excess capacity occurs in the pre-entry phase with $q^* = \mu < k^*$, provided that $V'(k) > z$ over $[m^A, \mu]$ where $\mu \neq n^A$.

(ii) If r is sufficiently large, the established firm holds no excess capacity in the pre-entry phase with $q^* = k^* < \mu$ and, in addition, if z is sufficiently large, builds additional capacity in the post-entry phase as the post-entry equilibrium is of type 1 with $k^* < m^A$.

III. If the market demand of the first period is great enough so that $\mu > n^A$, then the following statements are true.

(i) The established firm holds no excess capacity in the pre-entry phase with $q^* = k^* < \mu$.

[8]The simplest way to make the demand of the second period greater than that of the first period would be to uniformly shift out the first-period demand curve.

(ii) If r is sufficiently small, the post-entry equilibrium is either of type 2 with $m^A \leq q^* = k^* \leq n^A < \mu$ or of type 3 with $n^A \leq q^* = k^* < \mu$. In the latter case, the established firm holds excess capacity in the post-entry phase.

(iii) If r is sufficiently large, the post-entry equilibrium can be any of the three types, depending on the value of z.

***Proof*:** See Appendix.

In the above proposition, the case of $\mu < m^A$ represents the most favorable future relative to the present demand. On the other hand, the case of $n^A < \mu$ corresponds to the most unfavorable future. The remaining case $m^A \leq \mu \leq n^A$ is an intermediate situation.

The proposition thus says that if the market is certain to grow enough in the future, the established firm may hold excess capacity now in order to secure a cost advantage in competition with the entrant in the future, unless the cost of holding idle capacity is too large.[9] If it is too costly to leave some capacity idle, however, the established firm would rather keep its capacity at such a low level that it installs additional capacity in the post-entry stage. In this way, the established firm would choose to give up its first-mover advantage and compete on an equal footing with the entrant. When the prospect of the future market is unfavorable compared with the current market demand, the established firm is not likely to hold excess capacity now, even though the interest rate is very low. Some capacity may be left idle in the post-entry phase.

At this stage of the analysis, there might arise some doubt as to whether the first-period idle capacity is due to the established firm's desire to preempt the first-mover advantage or just out of a precautionary motive in expectation of the market growth.

[9]There is some cost associated with the capacity not being utilized in the first period. Let $\hat{k} \equiv k_1^A - q_1^A$. If $\hat{k} > 0$ so that there is some idle capacity in the first period. It is clear that, in the second period, the established firm's capacity will be utilized at least up to the level k_1^A. (Otherwise, the firm could cut costs without affecting its revenue through reducing the first-period capacity by a small amount.) Holding idle capacity by as much as $\hat{k}$, the firm incurs capacity cost $z\hat{k}$ which is unnecessary for the first-period production, but saves the second-period capacity cost by $z\hat{k}$. The net cost of the idle capacity is then $z\hat{k} - (1 + r)^{-1}z\hat{k}$ which reduces to $r(1 + r)^{-1}z\hat{k}$. For not too a high level of r, the established firm might be willing to pay $r(1 + r)^{-1}z\hat{k}$ in return for the first-mover advantage to be exercised in the second period.

To examine this query, let us consider the case in which a single firm faces no new entry during its two-period operations in the market. Assume the demand function and cost functions satisfy the usual convexity conditions to ensure that the firm's optimization program has a solution. Let k_j^* and q_j^* refer to the optimal capacity and output levels of period $j(j = 1, 2)$, respectively. Suppose excess capacity occurs in the first period, that is, $k_1^* - q_1^* > 0$. Let us then see what happens if the firm cuts its first-period capacity from k_1^* to q_1^*. If this reduction of the first-period capacity causes the firm to install additional capacity in the second-period in order to keep its second-period capacity and output at the original levels k_2^* and q_2^*, respectively, the additional investment is at most $k_1^* - q_1^*$ ($k_1^* - q_1^*$ if $k_2^* \geq k_1^*$ and less than $k_1^* - q_1^*$ if $k_2^* < k_1^*$). Therefore, the net gain from the capacity reduction (from k_1^* to q_1^*) is at least $z(k_1^* - q_1^*) - (1 + r)^{-1}z(k_1^* - q_1^*) = r(1 + r)^{-1}z(k_1^* - q_1^*)$ which is positive. This contradicts the optimality of k_j^* and q_j^*, meaning that there cannot be excess capacity in the first period under the monopoly regime. Consequently, the first-period idle capacity in Proposition 1 proved to be caused by the established firm's intent to preempt the first-mover advantage in the face of a new entrant.

The intuition behind Proposition 1 is as follows. When market demand remains constant over time as in Spulber (1981), the incumbent's production capacity at its monopoly days is likely to be more than enough to meet the equilibrium output of the post-entry game. The incumbent naturally exercises its first-mover advantage of not having to pay capacity cost while its rival should. When future demand is large enough, however, the current monopoly output is likely to fall short of the required output level in the post-entry equilibrium. So the incumbent must decide whether to install the additional capacity now or after new entry occurs. If the interest rate is not too high, holding excess capacity now costs the incumbent little but provides it with a cost advantage over its rival in the post-entry stage. If the interest rate is sufficiently high, the incumbent may be better off abandoning its first-mover advantage by delaying capacity installment until the post-entry phase and then competing on even terms with the new entrant.

This paper thus modifies the received conclusion of Spulber (1981) that it is irrational for the incumbent to hold pre-entry excess capacity when the post-entry game rule is Cournot-Nash. Accordingly, his conclusion that the Excess Capacity Hypothesis is only valid under quite limited conditions (that is, when the established firm is a Stackelberg leader) should also be altered.

TABLE 1
CONFIGURATION OF EQUILIBRIUM VALUES AND EXCESS CAPACITY

(a_1, a_2, γ)	q^*	k^*	m^A	n^A	q_2^{A*}	q^{B*}	excess capa. in period 1	excess capa. in period 2	additional capacity installation in period 2
(a) (3, 4, 0.1)	0.95	0.95	5/3	4/3	5/3	5/3	0	0	0.72
(b) (3, 6, 0.1)	1	1.9	4/3	2	1.9	1.05	0.9	0	0
(c) (3, 6, 0.8)	1.4	1.4	4/3	2	1.4	1.25	0	0	0
(d) (11, 6, 0.8)	4.78	4.78	4/3	2	2	1	0	2.78	0

IV. A Parametric Example with Implications for Antitrust Policy

In this section, we introduce specific functional forms of the market demand and cost functions and conduct a comparative static analysis by varying relevant parameters. Suppose the following:

Market demand: $p_1(q) = a_1 - q$ and $p_2(q) = a_2 - q(a_2 > 5)$.
Variable cost function: $c^A(q) = c^B(q) = q$.
Unit cost of capacity: $z = 1$.

Then it follows that $\pi'(q) = a_1 - 2q - 1$, $\mu = \frac{1}{2}(a_1 - 1)$, $\gamma_+^A(q) = \frac{1}{2}(a_2 - 2 - q), \gamma_-^A(q) = \frac{1}{2}(a_2 - 1 - q), \gamma^B(q) = \frac{1}{2}(a_2 - 2 - q)$, $(m^A, m^B) = \left(\frac{a_2 - 2}{3}, \frac{a_2 - 2}{3}\right)$, $(n^A, n^B) = \left(\frac{a_2}{3}, \frac{a_2 - 3}{3}\right)$, $V'(k) = 1\left(\text{if } k < \frac{a_2 - 2}{3}\right)$, $V'(k) = \frac{a_2}{2} - k\left(\text{if } \frac{a_2 - 2}{3} \le k \le \frac{a_2}{3}\right)$, $V'(k) = 0\left(\text{if } k > \frac{a_2}{3}\right)$.

Then, given the values of a_1, a_2, and r, we can calculate the numerical values of q^*, k^*, q_2^{A*}, and q^{B*} and see if excess capacity occurs in either the first or the second period. The Table 1 summarizes the result.

In (a) where the second-period demand is only moderately higher than the first-period demand, excess capacity does not occur. In (b), however, the second-period demand is double the first-period demand and the interest rate is low, so the established firm builds capacity in excess of the optimal output level for the first-period. In (c), compared with (b), demand conditions remain unchanged, but the interest rate is so high that holding excess capacity is too costly. Thus excess capacity is not observed here. In (d), the second-period demand is almost half the first-period demand. Excess capacity occurs in the second period.

A. *Is It Welfare-Improving to Restrain a Dominant Firm's Strategic Capacity Expansion?*

Now that pre-entry excess capacity can occur in the model of this paper, it is possible to examine the welfare effect of antitrust action against the established firm's strategic capacity expansion. In the history of the U.S. antitrust law practices, it is not difficult to find cases where a dominant firm in an industry was charged with violation of the law when it tried to expand capacity ahead of its rivals at such a high level that it far exceeded the current demand. One of the most exemplary cases is FTC's lawsuit in 1980 against DuPont for expanding the capacity of its Titanium Dioxide plant in anticipation of market growth.[10] Though Dupont's strategic capacity expansion turned out to be within the bounds of legitimate business practices, Dobson et al. (1994) remarks, the theory of FTC's complaint counsel that strategic deterrence behavior may at some point cross the line and become unreasonably exclusionary was not rejected. Since there has not been a theoretical model where an established firm's holding excess capacity occurs in equilibrium, it is worthwhile, though simply through our numerical model, to evaluate the argument for discouraging strategic capacity expansion for the cause of fostering competition.

Using parametric values given at (b), $(a_1, a_2, r) = (3, 6, 0.1)$ in Table 1, Table 2 compares the consumers, producers, and social surplus in the non-restriction case, which are calculated directly from the data in Table 1, with the corresponding surplus in the restriction case, which are derived by solving the optimization problem (13) with the inequality constraint replaced by $q^* = k^*$.

Knowing that holding excess capacity is not allowed in the pre-entry stage and that market demand is certain to grow in the next period, the established firm chooses to increase its first-period output in excess of the level which would have been optimal without the capacity restriction ($1 \rightarrow 1.28$). This increases the first-period consumers surplus ($0.5 \rightarrow 0.8192$). The entrant is then favored by the incumbent's output reduction of the second period, but not by enough to increase the second-period consumers surplus. The present value of consumers surplus over two periods turns out to be diminished ($4.45 \rightarrow 4.05$).

[10]See Dobson et al. (1994) for details.

TABLE 2
THE EFFECT OF EXCESS-CAPACITY REGULATION

	q^*	k^*	CS_1	CS_2	PS_1^A	PS_2^A	PS^B	CS	PS	SW
No Restriction	1	1.9	0.5	4.35	-0.9*	3.895	1.1025	4.4545	3.6432	8.097
Restriction	1.28	1.28	0.8192	3.55	-0.3584*	3.06	1.778	4.0465	4.0398	8.086

Note: 1. CS_t = consumer surplus at period t; PS_t^A = firm *A*'s profit at period t; PS^B= firm *B*'s profit;
2. $CS = CS_1 + (1.1)^{-1} CS_2$; $PS = PS_1^A + (1.1)^{-1} (PS_2^A + PS^B)$;
3. SW(social welfare) = $CS_1 + PS_1^A + (1.1)^{-1} (CS_2 + PS_2^A + PS^B)$.

*: These numbers are negative due to the cost of capacity which covers production over two periods.

Moreover, the present value of producers surplus over two periods increases as a result of the restraint (3.64 $\rightarrow$ 4.04). All told, social welfare is reduced as a result of the prohibitive action (8.097 $\rightarrow$ 8.086). We express this result as Proposition 2.

Proposition 2

Antitrust enforcement of restriction on strategic excess capacity may reduce social welfare as well consumers surplus to the contrary of its original intention of fostering competition.

Proposition 1 indicates that strategic capacity expansion is more likely to be observed when the market is growing faster. Moreover, we have noted that even if pre-entry excess capacity does not occur, the already-installed capacity may confer a first-mover advantage upon the established firm, provided that its pre-entry output is enough for the post-entry equilibrium. Proposition 2 further implies that it would be a mistake to simply equate pre-entry excess capacity with an anti-competitive behavior, and that capacity expansion should thus be viewed as a legitimate business response to the booming market rather than a harmful activity to be penalized.

Spulber (1989) also advises against antitrust action restricting strategic excess capacity. His policy advice, however, is based upon the conclusion of Spulber (1981) that excess capacity *cannot* occur if the post-entry game rule is Cournot-Nash.

V. Summary and Conclusion

By introducing variable demands, this paper has shown that the incumbent firm may hold excess capacity in the pre-entry stage even under the post-entry game rule of Cournot-Nash. Accordingly, Spulber's (1981) conclusion that the Excess Capacity Hypothesis is only valid under quite limited conditions (one of them is that the established firm is a Stackelberg leader) should be altered. It has also demonstrated that if the interest rate is sufficiently high under a booming prospect of the market, the incumbent may relinquish its first-mover advantage by choosing to install extra capacity in the post-entry phase and compete on an equal footing with the new entrant. An established firm's first-mover advantage is a matter of choice, not a predetermined condition. Therefore, preemptive investment needs not necessarily be associated with the incumbent firm's entry-deterring behavior.

These theoretical results, coupled with a numerical welfare analysis, have a practical implication that antitrust actions against capacity expansion by the established firm may reduce social welfare to the contrary of the original goal of fostering competition.

Appendix
Proof of Proposition 1

I. (i) Suppose that $k^* = q^*$. Since $q^* \leq \mu$ and $\mu < m^A$, it follows that $k^* = q^* < m^A$. If the established firm increases capacity from the current level k^* to $m^A + \varepsilon$ with other things being equal, the additional capacity cost is $(m^A + \varepsilon - k^*)z$, whereas the additional benefit is $(1 + r)^{-1}z(m^A - k^*)$ (caused by an increase of capacity from k^* to m^A) plus at least $(1 + r)^{-1}[\varepsilon z + \varepsilon \times \min\{V'(m^A), V'(m^A + \varepsilon)\}]$ (caused by an increase of capacity from m^A to $m^A + \varepsilon$). ($V'(\cdot)$ is monotone over $[m^A, m^A + \varepsilon]$ for a sufficiently small ε, since it is continuos over $[m^A, n^A]$ as can be seen from (7).) Therefore, for a sufficiently small ε, the net benefit is approximately $- r(1 + r)^{-1}(m^A + \varepsilon - k^*) + (1 + r)^{-1} \min\{V'(m^A), V'(m^A + \varepsilon)\}$ which converges to $\min\{V'(m^A), V'(m^A + \varepsilon)$($> z$ from (10)) as $r \to 0$. This means that k^* is not optimal. Therefore, $k^* > q^*$.

Then, from (16), we have $\lambda^* = 0$, implying $q^* = \mu$ from (14). $\lambda^* = 0$ leads also to $V'(k^*) = (1 + r)z$ from (15), or $(1 + r)^{-1}V'(k^* - \varepsilon) \geq z$ and $(1 + r)^{-1}V'(k^* + \varepsilon) \leq z$ for a sufficiently small $\varepsilon > 0$ from (15'). It follows from (5), (10), and (12) that $m^A < k^* \leq n^A$.

(ii) Suppose to the contrary that $q^* < k^*$. This implies $\lambda^* = 0$ from (16), and $V'(\cdot)$ is a bounded function from (5), (7) and (12)., Thus, neither (15) nor (15') can be satisfied for a sufficiently large r, because $\lim_{r \to \infty}(1 + r)^{-1}V'(k^*) = 0$. Therefore, for a sufficiently large r, we have $q^* = k^*$ and $\lambda^* >$

0, which leads to $q^* = k^* < \mu < m^A$.

II. (i) a. Suppose $k^* < m^A$. Then, $q^* \leq k^*$ and we assumed $m^A \leq \mu < n^A$, we have $q^* < \mu$ which implies $\lambda^* > 0$ from (14). It then follows from (14) and (17) that $q^* = k^* < m^A$. But, since $\lim_{r \to 0}(1 + r)^{-1}V'(k^*) = z$ from (5), neither (15) nor (15') can hold. Therefore, $k^* \geq m^A$.

Now suppose $n^A < k^*$. Then, since the second-period equilibrium is at point n from Figure 3, firm A is left with excess capacity. Moreover, the inequality $n^A < k^*$ implies $q^* \leq \mu < k^*$ which means some of the first-period capacity is also left idle. This contradicts the optimality of k^*. Therefore, $n^A \geq k^*$.

b. Suppose $V'(k) > z$ over $[m^A, \mu]$. If $\lambda^* > 0$, we have $q^* = k^* < \mu$. Since $k^* \geq m^A$ from II (i) *a*, we have $m^A \leq k^* < \mu$ which implies that $V'(k^*) > z$. Now, if firm A increases its capacity from k^* to $k^* + \varepsilon$ for a small ε. Then the net change in firm A's profit is approximately $\{(1 + r)^{-1}V'(k^*) - z\}\varepsilon$ which is greater than zero for a sufficiently small r. This contradicts the optimality of (q^*, k^*, λ^*). Therefore, $\lambda^* = 0$. Then, from (15), $\mu = q^* \leq k^*$. If $q^* = \mu = k^*$, firm A is better off by increasing its first-period capacity from μ to $\mu + \varepsilon$ because $V'(\cdot)$, as a continuous function, is greater than z over a small neighborhood of μ. Thus, $\mu = q^* < k^*$.

(ii) Suppose $\lambda^* = 0$. Then, we can find a large r for which neither (15) nor (15') holds, because $V'(k^*)$ is bounded as we can see from (5), (7), and (12). Thus, we have $\lambda^* > 0$ and $q^* = k^* < \mu$ from (14) and (16). As r gets larger, the left-hand side of (15) or (15') approaches $\pi'(k^*)$. As z also gets larger, in order for (15) or (15') to be satisfied, k^* must approach zero, whereas as z converges to zero, k^* must approach μ. Therefore, for a sufficiently large r, k^* can be either smaller or larger than m^A, depending on the value of z.

III. (i) Suppose $\lambda^* = 0$. Then, from (14), we have $q^* = \mu(> n^A)$, which implies $k^* > n^A$. It follows from (12) that $V'(k^*) = 0$. Then, none of (15) and (15') can be satisfied, because the left-hand side of either equation is zero, a contradiction. Therefore, $\lambda^* > 0$, thus $q^* = k^* < \mu$.

(ii) Now suppose $k^* \leq m^A$. Then, by (5), the left-hand side of (15) and (15') reduces to $\pi'(k^*)(> 0) + (1 + r)^{-1}z$ which cannot equal z for a sufficiently small r. Therefore, $k^* > m^A$. And, if (15) or (15') is satisfied for a certain $\tilde{k} \in (m^A, n^A]$, then it follows that $m^A < k^* \leq n^A$, whereas if $\pi'(k) + (1 + r)^{-1}V'(k) > z$ for any $k \in [m^A, n^A]$, then $k^* > n^A$.

(iii) In a similar way used for proving I (ii) and II (ii), $\lambda^* = 0$ cannot hold for a large r. Thus, we have $\lambda^* > 0$ which implies $q^* = k^*$. Then, left-hand-side of (15) and (15') reduces to $\pi'(k) + (1 + r)^{-1}V'(k^*)$ which converges to $\pi'(k^*)$ as r gets larger. As z gets larger, k^* approaches zero, whereas as z converges to zero, k^* approaches μ. Therefore, for a sufficiently large r, any of the inequalities $k^* < m^A$ or $m^A \leq k^* \leq n^A$ or $n^A < k^*$ can hold, depending on the value of z.

Q.E.D.

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