THE ROLE OF INVESTMENT IN ENTRY-DETERRENCE[*]

Avinash Dixit

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I.   Background

The theory of large-scale entry into an industry is made complicated by its game-theoretic aspects.   Even in the simplest case of one established firm facing one prospective entrant, there are some subtle strategic inter-actions.   The established firm's pre-entry decisions can influence the prospective entrant's view of what will happen if he enters, and the established firm will try to exploit this possibility to its own advantage.

The earliest treatments met these problems by adopting the Bain-Sylos postulate, where the prospective entrant was assumed to believe that the established firm would maintain the same output after entry as its actual pre-entry output.   Then the established firm naturally acquired a Stackelberg leadership role.   However, the assumption is dubious on two opposing counts. First, faced with an irrevocable fact of entry, the established firm will usually find it best to make an accommodating output reduction.   On the other hand, it would like to threaten to respond to entry with a predatory increase in output.   Its problem is to make the latter threat credible given the prospective entrant's knowledge of the former fact.   (A detailed exposition of the Bain-Sylos model and its critique can be found in Scherer (1970, ch. 8).)

In a seminal treatment of games involving such conflicts, Schelling (1960, ch. 2) suggested that a threat which is costly to carry out can be made credible by entering into an advance commitment which makes its fulfil-ment optimal or even necessary.   This was applied to the question of entry by Spence (1977), who recognised that the established firm's prior and irrevocable investment decisions could be a commitment of this kind.

He assumed that the prospective entrant would believe that the established firm's post-entry output would equal its pre-entry capacity. In the interests of entry-deterrence, the established firm may set capacity at such a high level that in the pre-entry phase it would not want to utilise it all, i.e. excess capacity would be observed.

The Bain-Sylos and Spence analyses were extended in Dixit (1979) by considering whether the established firm will find it best to prevent entry or to allow it to occur. However, the basic assumptions concerning the post-entry developments were maintained.

Since it is at best unclear whether such assumptions will be valid, it seems useful to study the consequences of some alternatives. In reality, there may be no agreement about the rules of the post-entry game, and there may be periods of disequilibrium before any order is established. Financial positions of the firms may then acquire an important role. However, even when the two have a common understanding of the rules of the post-entry duopoly, there are several possibilities. An obvious case is where a Nash equilibrium will be established after entry, either in quantities as in Cournot (see also Wenders (1971)) or in prices as in Bertrand. Yet another case is where the entrant is destined to take over Stackelberg leadership in setting quantities (see Salop (1978)).

In this paper I examine some of these possibilities. The basic point is that although the rules of the post-entry game are taken to be exogenous, the established firm can alter the outcome to its advantage by changing the initial conditions. In particular, an irrevocable choice of investment allows it to alter its post-entry marginal cost curve, and

thereby the post-entry equilibrium under any specified rule. It will be seen that it can use this privilege to exercise limited leadership.

II. The Model

The basic point is most easily seen in a simplified model. I shall reduce the dynamic aspects to the barest essentials by ignoring all lags. Either entry does not occur at all, in which case the established firm continues in a stationary state, or else it occurs at once, and the post-entry equilibrium is also established at once, so that the resulting duopoly continues in its stationary state. It is as if the two players see through the whole problem and implement the solution immediately.[*] The result is that we can confine attention to the constant streams of profits, avoiding the complication of reducing a varying pair of profit flows to discounted present values. However, once the underlying principle is understood, an added complication in this respect is not difficult to admit in principle.

The second simplification made in the main body of the analysis is with regard to the costs of production. Let the subscript 1 denote the established firm and 2 the prospective entrant. Each firm will be supposed to have a constant marginal cost up to its capacity level, and also a constant marginal cost of capacity expansion. If firm i has capacity k_i and is producing output x_i (with $x_i \leqslant k_i$), its cost per period will be

$$C_i = f_i + w_i x_i + r_i k_i \tag{1}$$

where f_i is the fixed set-up cost, r_i the constant cost per unit of

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[*] Compare the exchange between Moriarty and Holmes in The Final Problem: 'All that I have to say has already crossed your mind', said he. 'Then possibly my answer has crossed yours', I replied.

capacity (both expressed in per period equivalents) and w_i the constant average variable cost of output. In the fourth section I will indicate what happens with a more general cost function.
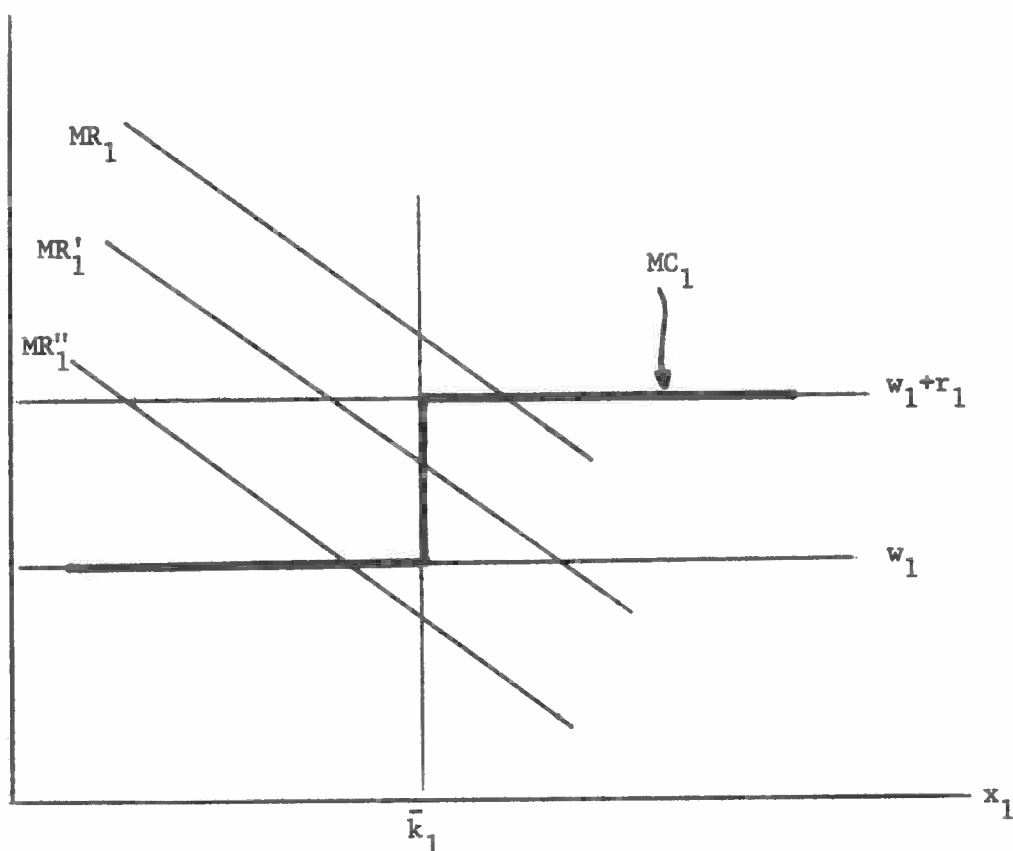
The revenues per period for the two firms will be functions $R^i(x_1, x_2)$. Each will be increasing and concave in that firm's output. Also, each firm's total and marginal revenue will be decreasing in the other's output.

The rules of the game are as follows. The established firm chooses a pre-entry capacity level $\bar{k}_1$. This may subsequently be increased, but cannot be reduced. If the other firm decides to enter, the two will achieve a duopoly Cournot-Nash equilibrium with quantity-setting. Otherwise the established firm will prevail as a monopoly.

First consider what happens for a given level of $\bar{k}_1$. Firm 1's marginal cost is w_1 so long as its output level does not exceed $\bar{k}_1$, and (w_1+r_1) thereafter. Its reaction function therefore depends on its initial capacity choice. Firm 2's marginal cost is always (w_2+r_2), as it has no previous commitment to capacity. But the Nash equilibrium that results depends on $\bar{k}_1$, and therefore so do the profits of the two firms in it. If the profits for the second firm are positive, it will enter; otherwise it will not. Bearing this in mind, firm 1 will choose that $\bar{k}_1$ which maximises its profit. Whether this is done by preventing entry or by allowing it to occur remains to be seen. However, I shall assume for simplicity of exposition that the established firm's maximum profit is positive, i.e. exit is not its best policy.

The analysis follows the scheme just outlined. For a given $\bar{k}_1$, Figure 1 shows the marginal cost curve for the established firm, MC_1 ,

Figure 1

Figure showing MR curves labelled MR_1, MR_1', MR_1'' on the vertical axis, MC_1, the horizontal lines w_1+r_1 and w_1, the vertical reference line at $\bar{k}_1$, and the horizontal axis x_1.

as the heavy kinked line. It equals w_1, the marginal cost when there is spare capacity, up to the output level $\bar{k}_1$ and (w_1+r_1), the marginal cost including capacity expansion cost, thereafter. On this we super-impose the marginal revenue curve the position of which depends on the assumed output level x_2 of the other firm. For a sufficiently low value of x_2 , the curve is in a position like the one labelled MR_1, and the first firm's profit-maximising choice of x_1 lies to the right of its

previously fixed capacity level.   For successively higher levels of x_2,
the marginal revenue curve shifts downwards   to occupy positions like
MR_1' and MR_2'' , yielding choices of x_1 at, or below, the capacity level.
This response of x_1 to x_2 is just the established firm's reaction
function to the entrant's output.

This function can be shown in a more familiar direct manner in
the space of the two quantities, and this is done in Figure 2.   I have
shown two 'reference' curves MM' and NN'.   The first becomes   the re-
action function if capacity expansion costs matter, and the second if
there is spare capacity.   Therefore the first is relevant for outputs
above $\bar{k}_1$ and the second for outputs below this level. . For fixed $\bar{k}_1$,
then, the reaction function is the kinked curve shown in heavy lines.

Figure 2
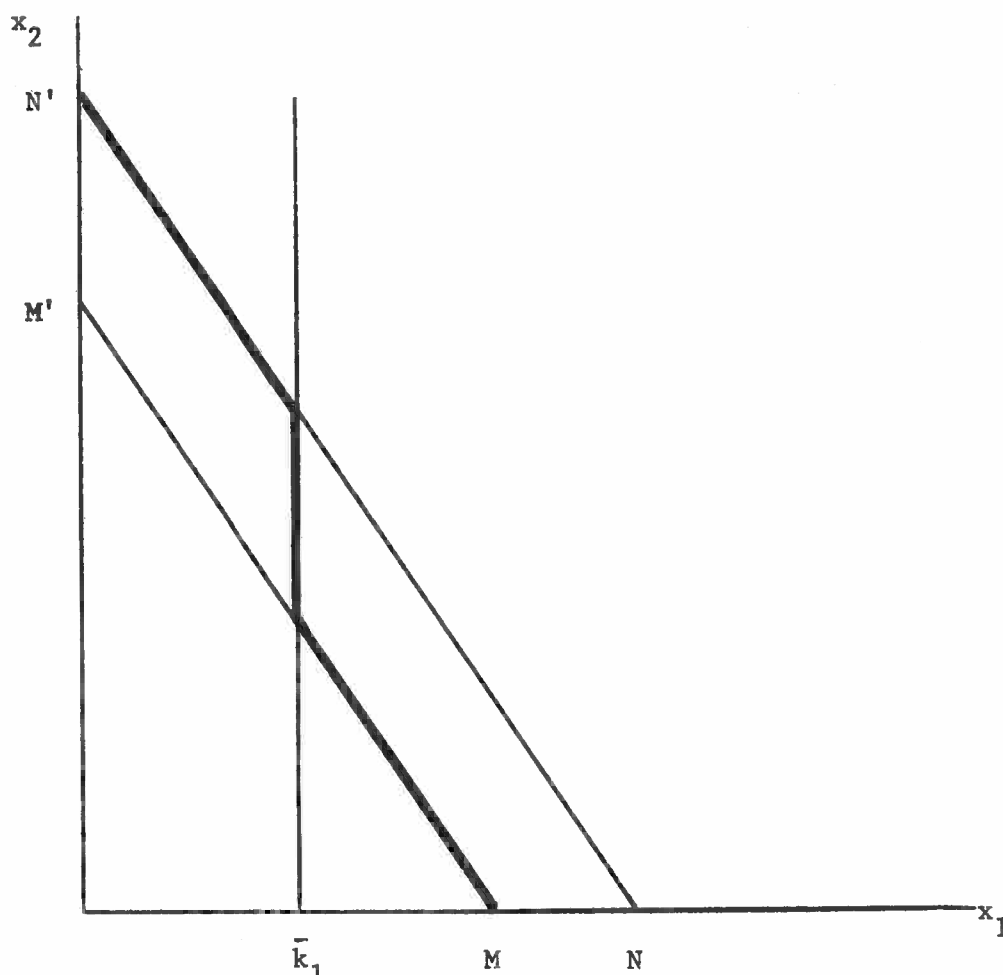
Let the points M and N have respective coordinates $(M_1, 0)$ and $(N_1, 0)$. The quantities M_1 and N_1 can be interpreted as follows. Both are profit-maximising quantity choices of firm 1 when the output level of firm 2 is held fixed at zero, i.e. when the possibility of entry is ignored. However, M_1 is the choice when capacity expansion costs matter, and N_1 is relevant when there is sufficient capacity already installed and only variable costs matter.

Since firm 2 has no prior commitment in capacity, its reaction function RR' is straightforward. I assume that it intersects both MM' and NN' in a way that corresponds to the usual 'stable' Cournot solution, in order to minimise complications other than those of immediate interest (see Figure 3).

Figure 3
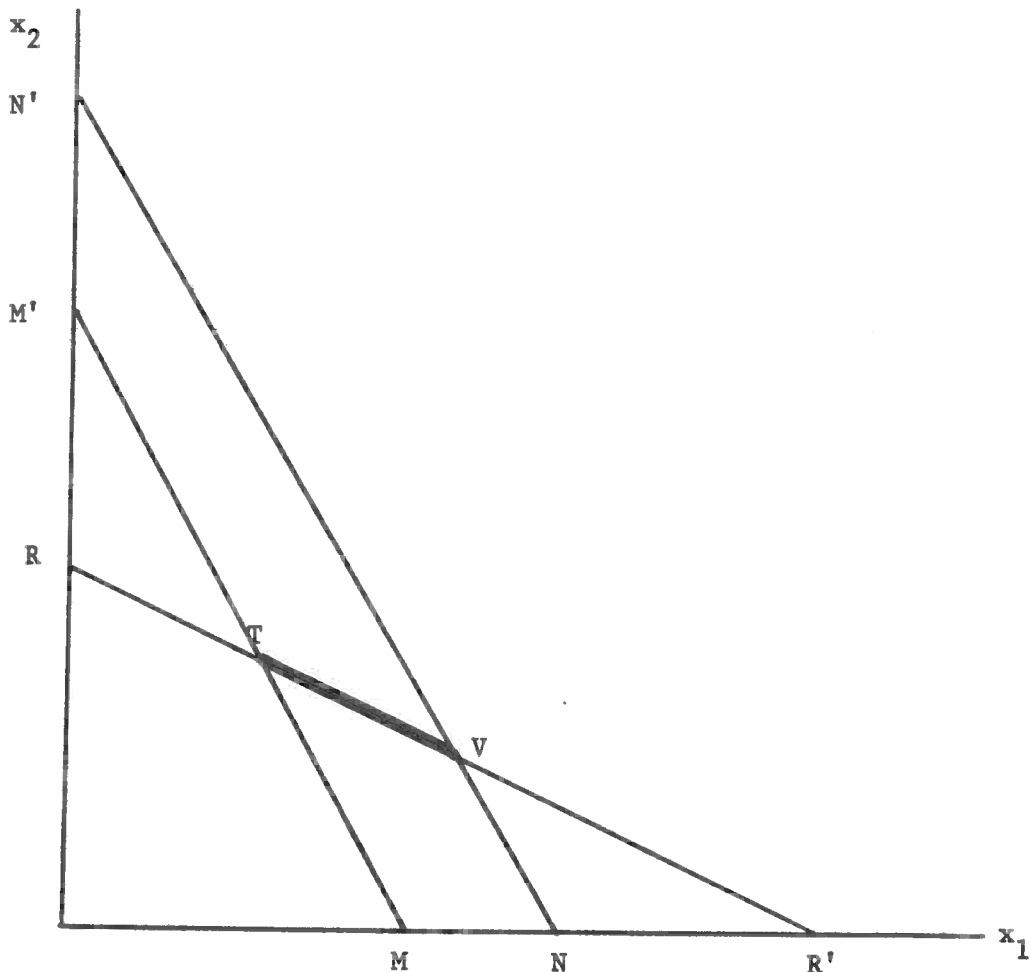
For given $\bar{k}_1$, we have a duopoly Nash equilibrium at the intersection of the two reaction functions. However, the established firm has the privilege of choosing $\bar{k}_1$ in advance, and thus determining which reaction function it will present in the post-entry duopoly. Suppose firm 2's reaction function meets MM' at $T = (T_1, T_2)$ and NN' at $V = (V_1, V_2)$ as shown in Figure 3. Clearly T and V can be interpreted as Nash equilibria under alternative extreme circumstances, T when capacity expansion costs matter for firm 1, and V when they do not. It is then evident on comparing Figures 2 and 3 that for a choice of $\bar{k}_1 \leqslant T_1$, the post-entry equilibrium will be at T, while for $\bar{k}_1 \geqslant V_1$, it will occur at V. Most importantly, for $T_1 \leqslant \bar{k}_1 \leqslant V_1$, it will occur at the appropriate point on the heavy line segment of the entrant's reaction function lying between T and V. Here the established firm will produce output $x_1 = \bar{k}_1$, and the entrant will produce the same output as would a Stackelberg follower faced with this x_1. It is in this sense that, even when the post-entry game is accepted as leading to a Nash equilibrium, the established firm can exercise leadership over a limited range by using its capacity choice to manipulate the initial conditions of that game.

However, the qualification of the limited range is important. In particular, it means that capacity levels above V_1 are not credible threats of entry-deterrence. When a prospective entrant is confident of its ability to sustain a Nash equilibrium in the post-entry game, it does not fear such levels. And when the established firm knows this, it does not try out the costly and empty threats.

Since $N_1 > V_1$, we see a fortiori the futility of maintaining capacity levels above N_1 as threats to deter entry. Nor are such capacity

levels justified by considerations of pre-entry production; in fact a
monopolist saddled with capacity above N_1 will choose to leave the
excess idle. Under the rules of the game assumed here, therefore,
we will not observe the established firm installing capacity above N_1.
The Spence excess capacity strategy will not be employed.

In the model used by Spence, it is simply assumed that a prospective
entrant expects the established firm will respond to entry by producing
an output level equal to its pre-entry capacity, no matter how high that
may be. It is then possible that constrained monopoly profits made by
keeping capacity at the entry-deterring level and producing at N exceed
what is possible with a lower capacity leading to a Stackelberg duopoly
equilibrium. When the credibility of the threat is questioned, matters
can be different, and the above argument shows that they are indeed
different under the particular modification of the rules of the game.

Nor will we ever see the established firm installing pre-entry
capacity of less than T_1: if entry is to occur it will want more
capacity, and if entry is not to occur it will want capacity of at least
$M_1 > T_1$.

III.   Classification of Outcomes

The discussion so far was confined to the post-entry duopoly, i.e.
both firms were assumed to have incurred the set-up costs. When we come
to the ex ante decision about whether to enter, set-up costs matter, and
the choice is governed by the sign of the profits net of them. (Dixit
(1979) uses an alternative geometric approach involving discontinuous re-
action functions.)

We have seen above that at all points that are ever going to be observed without or with entry, the established firm will be producing an output equal to its chosen pre-entry capacity. Therefore we may write the profits of the two firms as functions of their outputs alone, i.e.

$$\pi_i(x_1, x_2) = R^i(x_1, x_2) - f_i - (w_i + r_i)\, x_i \, .$$

It will often be convenient to indicate the point of evaluation (x_1, x_2) by a letter label such as that used in the corresponding figure. I have assumed that the maximum value of π_1 is always positive. Depending on the sign of π_2, various cases arise. Note that along firm 2's reaction function, its profit decreases monotonically from T to V. Therefore we can classify the possibilities as follows.

Case 1: $\pi_2(T) < 0$. Now the prospective entrant cannot make a profit in any post-entry equilibrium. So it will not try to enter the industry at all. Entry being irrelevant, the established firm will enjoy a pure monopoly by setting its capacity and output at M_1.

Case 2: $\pi_2(V) > 0$. Here the prospective entrant will make a positive profit in any post-entry equilibrium, so the established firm cannot hope to prevent entry. It can only seek the best available duopoly position. To this end, it will compute its profit along the segment TV. Since all these choices involve output equal to capacity, we can simply use the conventional iso-π_1 contours in (x_1, x_2) space and find the highest contour along the segment TV. If there is a Stackelberg tangency to the left of V, that is firm 1's best choice. However, if the conventional tangency occurs to the right of V, we now have a corner solution at V, which can then be thought of as a sort of generalised

Stackelberg leadership point.

Case 3: $\pi_2(T) > 0 > \pi_2(V)$. This presents the richest set of
possibilities.   Now there is a point $B = (B_1, B_2)$ along TV such that
$\pi_2(B) = 0$.   If the established firm sets its capacity above B_1, the
prospective entrant will reckon on making a negative profit in the post-
entry Nash equilibrium, and therefore will not enter. Thus the capacity
level B_1 is the entry-barring level.   Knowing this, firm 1 wants to
know whether it is worth its while to prevent entry.

Sub-case i :   If $B_1 < M_1$, then the established firm's monopoly choice
is automatically sufficient to deter entry. In Bain's terminology,
entry can be said to be blockaded.

If $B_1 > M_1$, the established firm can only bar entry by
maintaining capacity (and output) at a level greater than it would want
to as a monopolist;   thus it is faced with a calculation of the costs
and benefits of entry-prevention.   To prevent entry, it needs a
capacity of just greater than B_1.   Since $B_1 < V_1 < N_1$, we know that
it will want to use all this capacity in its monopoly choice of output,
so its profit will be $\pi_1(B_1, 0)$.   The alternative is to allow entry
and settle for the best duopoly point, which may be a tangency in the
segment TV, or a corner solution at V. Whichever it is, call it the
generalised Stackelberg point S, with coordinates (S_1, S_2). Then we
have
Sub-case ii : $\pi_1(S) < \pi_1(B_1, 0)$, when it is better to prevent entry
by choosing a limit-capacity or limit-output at B_1. There is a
corresponding limit-price. In Bain's usage, entry is effectively impeded.

Incidentally, for this sub-case to arise, it is sufficient to have $S_1 \geq B_1$. For, with $B_1 > M_1$, we have $\pi_1(S_1, S_2) < \pi_1(S_1, 0) \leq \pi_1(B_1, 0)$.

Sub-case iii : $\pi_1(S) > \pi_1(B_1, 0)$, when it is better to allow entry, i.e. entry is ineffectively impeded, and a duopoly solution is observed at S. Remember that S is the post-entry Nash equilibrium.

An alternative way of distinguishing between the sub-cases ii and iii is to draw the iso-π_1 contour through S and seeing if it intersects the x_1-axis to the right or the left of B_1. This would follow Dixit (1979), except for one new feature : the Stackelberg point S can be at the corner solution V.

For particular demand functions, we can evaluate all these profit expressions explicitly, and thereby express the classification of outcomes in terms of the underlying parameters.

IV.   Extensions and Modifications

Of the numerous extensions conceivable, I consider three. The first involves an alternative and rather extreme post-entry equilibrium, where the rules of the game are that the entrant acquires the role of quantity leadership (see Salop (1978)). Thus firm 2 chooses a point on firm 1's post-entry reaction function to maximise its own profit. However, firm 1, by its initial commitment to capacity, can decide which reaction function to present to the entrant, and can manipulate this choice to its own advantage.

Figure 4 shows the possibilities. The notation is the same as in Figure 3, with some additions. Let $F = (F_1, F_2)$ be the ordinary Stackelberg

Figure 4
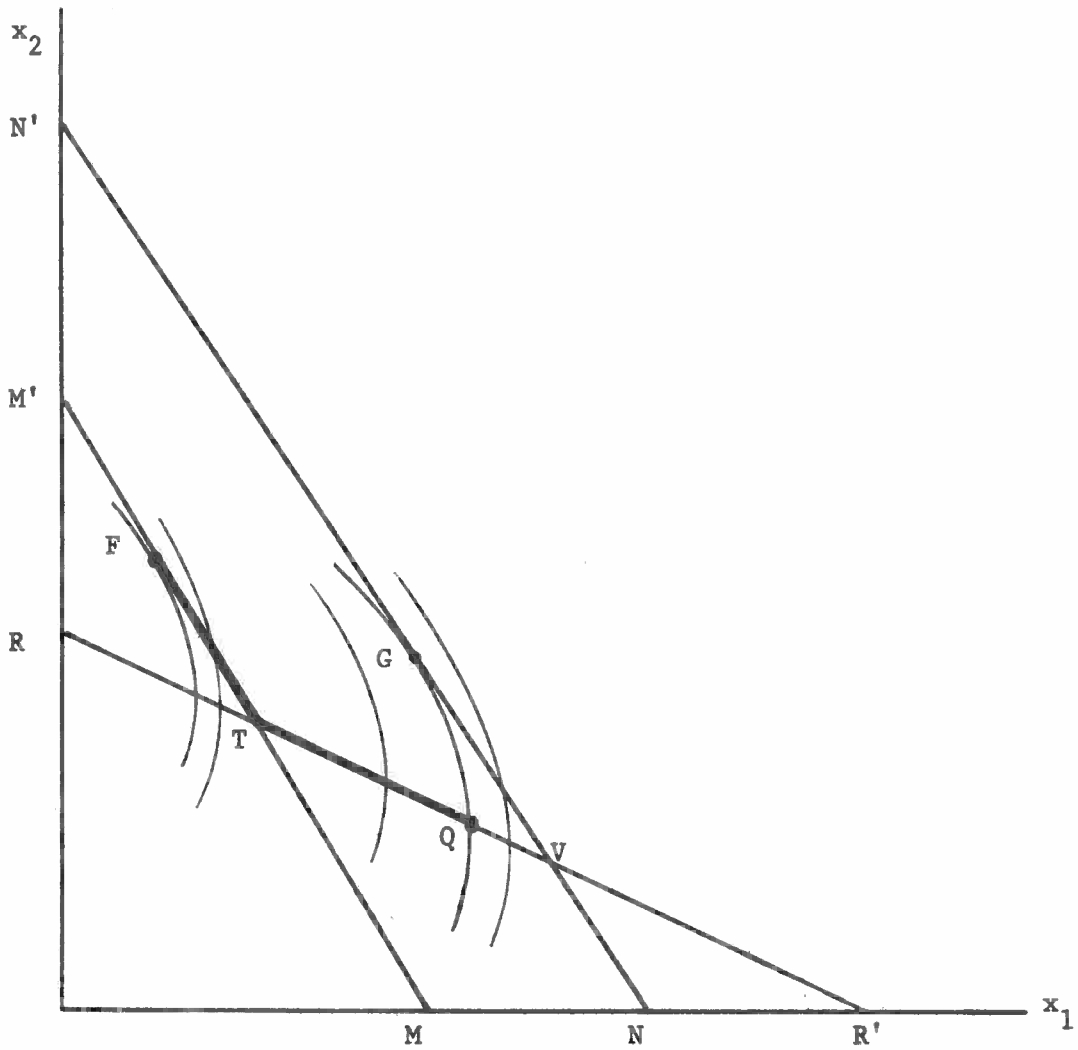
point where firm 2 is the leader and firm 1 the follower, taking into
account capacity expansion costs, i.e. using the reference curve
If firm 1 sets its capacity $\bar{k}_1$ at a level less than F_1, then its
reaction function as drawn in Figure 2 will drop from NN' to MM' at $\bar{k}_1$
to the left of F. Firm 2's profit will then be maximised on this
reaction function at the tangency point F. For $\bar{k}_1$ between F_1 and T_1,

there will be a maximum at the kink in firm 1's reaction function where it meets MM', yielding an equilibrium at the appropriate point along the segment FT. For a while to the right of T, we will have a tangency solution along TV, an iso-π_2 contour being tangential to the vertical portion of firm 1's reaction function. Let G be the point where an iso-π_2 contour is tangential to NN', and let this contour meet RR' at $Q = (Q_1, Q_2)$. Then the vertical tangency will be the best choice for firm 2 so long as $\bar{k}_1 \leq Q_1$. For $\bar{k}_1 > Q_1$, however, it will prefer the tangency at G.

By its choice of $\bar{k}_1$, the established firm can therefore secure as the post-entry equilibrium any point along the kinked line segment FTQ, shown in heavy ink in the figure, and the isolated point G. In other words, even though the rules of the game require it to surrender post-entry quantity leadership, the established firm can use its commitment to capacity to seize a limited initiative back from the entrant. It remains to choose the best available point. Now G is clearly inferior from the point of view of firm 1 to the point directly below it on the segment TQ. Similarly, all points along FT are worse than T. However, there is a genuine choice to be made, i.e. leadership exercised, along the segment TQ. This is smaller than the segment TV which was available when the post-entry rules led to a Nash equilibrium. But the qualitative features are unchanged, and all of my earlier analysis applies on replacing V by Q throughout.

The second extension I consider allows a more general cost function. The form (1), for a given capacity level, has marginal cost constant at the level w_1, and since capacity cannot be exceeded, the marginal cost of output can be said to jump to infinity where output hits

capacity. An increase in capacity then lowers marginal cost from infinity to w_1 over the added range. Now I replace this by a form which has a more flexible notion of capacity. Let

$$C_1 = C^1(x_1, k_1) \qquad (2)$$

This will be increasing in x_1, and convex at least beyond a certain point. For each x_1, there will be a cost-minimising choice of k_1, so C^1 will be decreasing in k_1 up to this level and increasing thereafter. Finally, a higher level of k_1 will lower marginal cost of output, i.e.

$$C^1_{x_1 k_1} < 0 \qquad (3)$$

with subscripts denoting partial derivatives in the usual way. All this follows the theory of the familiar textbook short run cost functions. This is similar to the more general model in Spence (1977) except that price discipline does not break down completely after entry.

Begin with the post-entry Nash equilibrium given that firm 1 has set its capacity variable at the level $\bar{k}_1$. Firm 2's reaction function is again straightforward. That for firm 1 is found by choosing x_1 to maximise

$$R^1(x_1, x_2) - C^1(x_1, \bar{k}_1)$$

for given x_2 and $\bar{k}_1$. This has the first-order condition

$$R^1_{x_1}(x_1, x_2) - C^1_{x_1}(x_1, \bar{k}_1) = 0 \qquad (4)$$

and the second-order condition

$$R^1_{x_1x_1}(x_1,x_2) - C^1_{x_1x_1}(x_1,\bar{k}_1) < 0 \qquad (5)$$

Equation (4) defines firm 1's post-entry reaction function, and also tells us how it shifts as $\bar{k}_1$ changes. Total differentiation gives

$$dx_1 = \left[- R^1_{x_1x_2}/(R^1_{x_1x_1} - C^1_{x_1x_1}) \right] dx_2 + \left[C^1_{x_1k_1}/(R^1_{x_1x_1} - C^1_{x_1x_1}) \right] d\bar{k}_1$$

Given our assumption that the commodities are substitutes in the sense that an increased quantity of the second lowers the marginal revenue for the first, and using (5), we see that the reaction function slopes downward. Also, using (3) and (5), we see that it shifts to the right as $\bar{k}_1$ increases.

Figure 5 shows a collection of firm 1's reaction functions for different choices of $\bar{k}_1$, as a set of dashed lines. Where each meets firm 2's reaction function RR', there is a post-entry Nash equilibrium for the

Figure 5
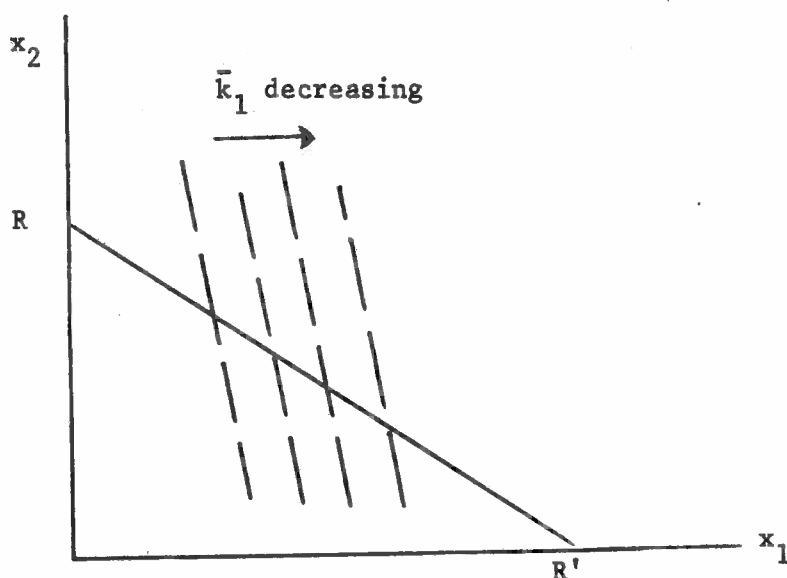
appropriate choice of $\bar{k}_1$. Thus, once again, firm 1 by its choice of capacity can achieve any one of a range of points along firm 2's reaction function. This is almost as if it acquired the privilege of quantity leadership. There are two limitations. First, the possible reaction functions found by varying $\bar{k}_1$ may trace out only a limited part of firm 2's reaction function, as happened in the case of section II. Secondly, in any post-entry Nash equilibrium, the $\bar{k}_1$ which achieves it is not the ideal choice for producing the x_1 that prevails there; so the policy involves a cost that does not appear in straightforward quantity leadership. To see this, we must examine the equilibrium in more detail. Firm 2 maximises $R^2(x_1,x_2)-C^2(x_2)$ in obvious notation, so its reaction function is given by

$$R^2_{x_2}(x_1,x_2) - C^2_{x_2}(x_2) = 0 \ . \tag{6}$$

Then (4) and (6) define the duopoly equilibrium as a function of $\bar{k}_1$. Differentiating the equations totally, we have

$$\begin{bmatrix} R^1_{x_1x_1} - C^1_{x_1x_1} & R^1_{x_1x_2} \\ \\ R^2_{x_1x_2} & R^2_{x_2x_2} - C^2_{x_2x_2} \end{bmatrix} \begin{bmatrix} dx_1 \\ \\ dx_2 \end{bmatrix} = \begin{bmatrix} C^1_{x_1k_1} & d\bar{k}_1 \\ \\ 0 \end{bmatrix} \tag{7}$$

Write Δ for the determinant of the coefficient matrix; it is positive by the stability condition for the equilibrium. Then we have the solution

$$\begin{bmatrix} dx_1 \\ \\ dx_2 \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} R^2_{x_2x_2} - C^2_{x_2x_2} \\ \\ - R^1_{x_1x_2} \end{bmatrix} C^1_{x_1k_1} \quad d\bar{k}_1 \tag{8}$$

Firm 1 uses this in its choice of $\bar{k}_1$ to maximise its profit, therefore

$$d\pi_1 \quad = \quad (R^1_{x_1} - C^1_{x_1}) \, dx_1 + R^1_{x_2} \, dx_2 - C^1_{k_1} \, d\bar{k}_1$$

$$= - (R^1_{x_2} \, R^2_{x_1 x_2} \, C^1_{x_1 k_1} \, / \, \Delta \, + \, C^1_{k_1}) \, d\bar{k}_1 \qquad (9)$$

At the best duopoly point, the coefficient of $d\bar{k}_1$ in (9) is zero. Since all three factors in the numerator of the first term are negative while Δ is positive, we see that at this point,

$$C^1_{k_1} \quad > \quad 0$$

i.e. firm 1 carries its capacity to a point beyond what is optimum for producing its output.

Once again the analysis can be completed by examining the sign of firm 2's profits, and the desirability of entry-prevention for firm 1. This more flexible notion of capacity can be interpreted in terms of other types of investment such as dealer networks and advertising, and this provides a basis for arguments that such expenditures can be used by an established firm in its efforts to deter entry. This counters recent expressions of pessimism (e.g. Needham (1978, pp. 177-9)) concerning the effectiveness of such tactics.

For the last modification, I revert to a rigid concept of capacity, but consider price-setting in the post-entry duopoly, the solution rule being the Bertrand-Nash equilibrium. Some added complications can arise due to possible non-convexities even with reasonable demand and cost functions, but I ignore these and show the simplest possible case. This is done in Figure 6,

Figure 6
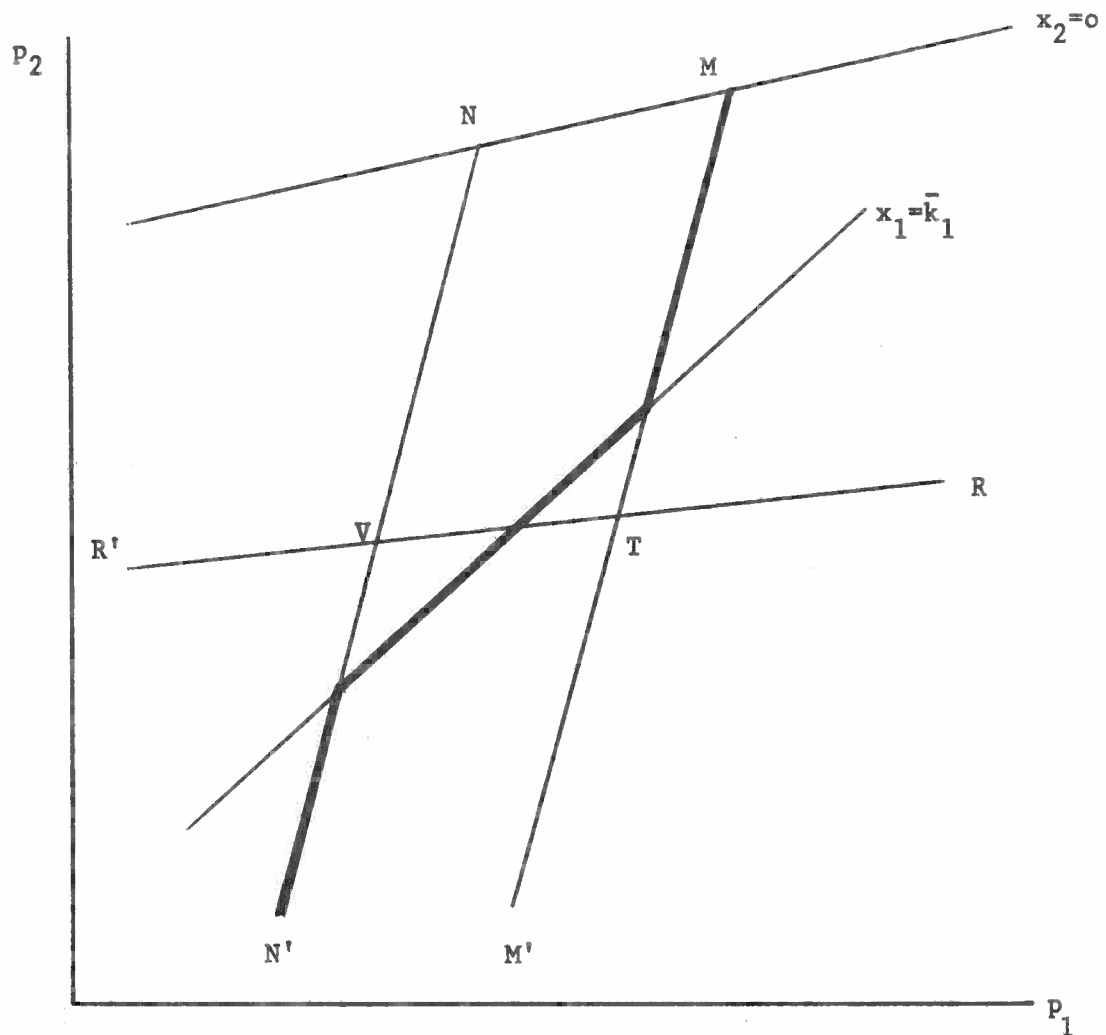
with notation analogous to the corresponding quantity-setting case of Figure 3. The prospective entrant's reaction function is RR'. For the established firm, we have two reference curves MM' and NN', the former when capacity expansion costs matter and the latter when they do not. Their relative positions are naturally reversed as compared to the quantity-setting case. The former is relevant for $x_1 \geq \bar{k}_1$ and the latter for $x_1 \leq \bar{k}_1$,

where x_1 is found from the demand function $D^1(p_1, p_2)$. The boundary curve $x_1 = \bar{k}_1$ is shown for a particular $\bar{k}_1$, and the corresponding reaction function for the established firm is shown by the heavy lines. It is then clear that by varying $\bar{k}_1$, the established firm can secure any point along the segment TV of the prospective entrant's reaction function as the post-entry Nash equilibrium. Once again, we observe a limited leadership possibility arise by virtue of the established firm's advantage in being the first to make a commitment to capacity.

V.   Concluding Comments

The theme of the paper is that the role of an irrevocable commitment of investment in entry-deterrence is to alter the initial conditions of the post-entry game to the advantage of the established firm, for any fixed rule under which that game is to be played. This was illustrated in several simple models. Prominent among the conclusions was the observation that if the post-entry game is agreed to be played according to Nash rules, the established firm will not wish to instal capacity that would be left idle in the pre-entry phase. The question of whether the established firm can modify the very rules of the post-entry game in its favour seems much more difficult.

Salop (1979) provides some examples of similar prior commitments that create an advantage for the established firm. Spence (1977a) can be thought of as developing the same theme. In his model, capacity can only be acquired slowly, and the two firms differ in their abilities in this regard. This difference governs how the industry evolves, including issues of whether the second firm will enter, and what kind of equilibrium will result if it does. Much of the interesting dynamics is lost in my formulation,

but the compensating advantage is that the basic idea can be grasped that much more transparently.

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