Economics Letters 18 (1985) 265–269
North-Holland

COMMITMENT AND ENTRY-DETERRENCE IN A MODEL OF DUOPOLY

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Received 12 December 1984

It has been claimed that excess capacity can be an effective tool for deterring entry. This paper argues that excess capacity can have two dimensions and to recognise this is to recognise the possibility of certain new kinds of industry equilibria. Two such equilibria are illustrated: one which is a perfect equilibrium and in which entry is thwarted even in the absence of excess capacity; and the other where entry is deterred by undertaking excess production and using the threat of dumping.

1. Commitment and capacity

The possibility of firms using excess capacity to deter entry in an oligopoly has been discussed by several economists [Wenders (1971), Spence (1977), Dixit (1979,1980)]. What is generally referred to as 'excess capacity' in this literature actually represents 'prior cost-commitments', that is, commitments of the incumbent firm to buy certain amounts of factors of production in excess of what it needs for its supply. The purpose of this note is to generalise the standard formulation of such prior commitments and to show that this can lead to some interesting duopoly equilibria which cannot be captured in the Spence (1977)–Dixit (1979) framework.

Consider a duopoly with firm 1 as the incumbent. Its cost function is specified by Dixit as follows:[1]

$$\begin{aligned} C_1 &= f_1 + (v_1 - r_1)x_1 + r_1 k_1 \quad \text{if} \quad x_1 \le k_1, \\ &= f_1 + v_1 x_1 \qquad\qquad\qquad\ \ \text{if} \quad x_1 \ge k_1, \end{aligned} \tag{1}$$

where x_1 is output, k_1 'capacity' (measured in the same units as output), f_1 fixed cost, v_1 total cost of each unit of output, r_1 cost per unit of capacity and C_1 total cost.

In fig. 1, k_1 is capacity (or 'prior commitment'). If a firm produces $x_1 < k_1$, then $CDEF$ is the value of wasted capacity. The total cost of producing x_1 is $ABCDE0$. The marginal cost of output expansion is represented by BC. If $x_1 = k_1$, the marginal cost of output expansion is given by BF.

In the models of Dixit and Spence, a firm is free to choose k_1, but r_1 is given exogenously. We allow the firm to choose $r_1 \in [0, v_1]$. This captures the notion that a firm may have, e.g., the land

[1] An alternative cost function with prior commitment is $C_1 = f_1 + \max\{v_1 x_1, K\}$, where K is the committed expenditure on inputs. If, in our model, all inputs were perfect substitutes, (1) would coincide with the above cost function.

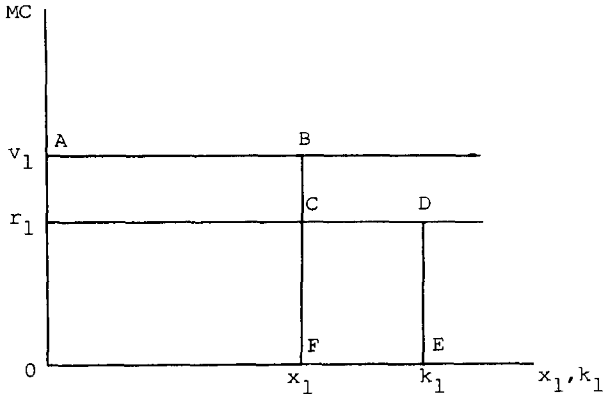

Fig. 1.

ready for k_1 units of output, or land plus buildings plus machinery, or output ready in inventori etc.

In Wenders (1971), Spence (1977) and Dixit (1979), all threats are treated as credible. Extendi this to our framework runs into difficulties. If at all levels of r_1 the threat remains credible, it is b for firm 1 to set r_1 always equal to zero, that is, precommit nothing. Also, in game-theoretic ter such equilibria may not be perfect. In Dixit (1980) equilibria are perfect: the only credible threats ones which have a zero cost of carrying-out. We encompass both approaches. In our model, a threa credible if the cost of carrying it out is below a prespecified level. If this prespecified level is ze clearly the equilibrium is perfect. We construct two examples, the first of which is a perf equilibrium.

2. The model

Let the demand curve facing the duopoly be

$$p = \alpha - \beta(x_1 + x_2),$$

where p is price, x_i the amount of good i supplies. The cost function of firm 1 (the incumbent given by (1), which may be rewritten as

$$C_1 = f_1 + (v_1 - r_1)x_1 + r_1 \max\{k_1, x_1\}.$$

Firm 2 (the potential entrant) does not ever precommit costs, and so its cost function is sim

$$C_2 = f_2 + v_2 x_2.$$

Firm 2 can choose to enter the industry or not. If it enters it acts like a Stackelberg follower, selec x_2 in response to x_1 which is embodied in its reaction function

$$x_2 = R(x_1).$$

It is easy to check that $R(\ )$ consists of two linear segments and a discontinuity (assuming $f_2 > 0$ shown in fig. 2. ABB_1D is the reaction curve.

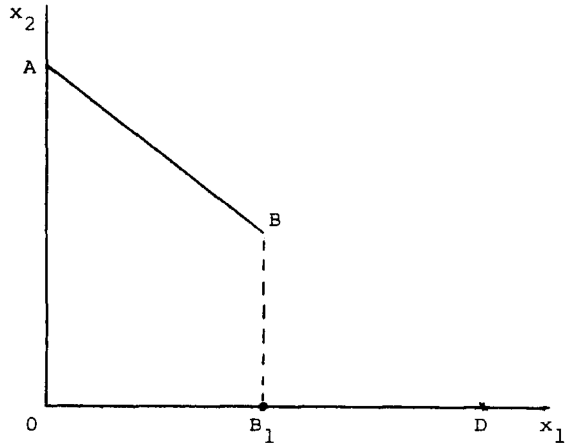

Fig. 2.

We use B_1 to denote the smallest output of firm 1 at which firm 2 produces no output. It should be clear that *we are distinguishing between (i) firm 2's decision to enter and produce zero, and (ii) firm 2's decision not to enter.* Since firm 1 can induce firm 2 to produce zero by itself producing infinitesimally more than B_1, we assume for ease of exposition that B itself is not on the reaction curve.

Let D be a variable which takes two values: 0 and 1, representing (respectively) firm 2's non-entry and entry. Hence firm 1's profit, π, is given by

$$\pi_1 = \pi_1(x_1, r_1, k_1, D)$$

$$= \begin{cases} [\alpha - \beta\{x_1 + R(x_1)\}]x_1 - f_1 - (v_1 - r_1)x_1 - r_1 \max\{k_1, x_1\} & \text{if} \quad D = 1, \\ [\alpha - \beta x_1]x_1 - f_1 - (v_1 - r_1)x_1 - r_1 \max\{k_1, x_1\} & \text{if} \quad D = 0. \end{cases} \tag{2}$$

The way firm 1 may deter entry is to announce that it will sell B_1 units should firm 2 decide to enter (which will be referred to, in brief, as *the threat*). It is assumed that this threat will be credible to firm 2 if the cost, ϕ, of carrying out the threat is less than a certain amount, say F. Let us now formalise the notion of 'the cost of carrying out the threat'. A special case is where $F = 0$; the solution then is a perfect equilibrium.

Suppose firm 1 selects (r_1, k_1) and announces the threat but firm 2, nevertheless, enters. Then the maximum profit firm 1 can earn is

$$\max_{x_1} \pi_1(x_1, r_1, k_1, 1) \equiv \tilde{\pi}_1(r_1, k_1).$$

If firm 1 responds to firm 2's entry by carrying out his threat, that is, by selling B_1 units of good 1, then his profit is [2]

$$\pi_1(B_1, r_1, k_1, 1) \equiv \bar{\pi}_1.$$

[2] It is easily verified that $\bar{\pi}_1$ is independent of r_1, k_1 and D. The last-named is so because whether firm 2 enters or not, when firm 1 produces B_1, firm 2 produces zero. Hence, $\bar{\pi}_1 = [\alpha - \beta B_1]B_1 - f_1 - v_1 B_1$.

Hence, it is reasonable to define the cost of carrying out the threat as follows:

$$\phi(r_1, k_1) = \tilde{\pi}_1(r_1, k_1) - \bar{\pi}_1.$$

Firm 1's threat is credible if

$$\phi(r_1, k_1) \le F.$$

In other words,

$$D = 0 \quad \text{if 1 makes threat and} \quad \phi(r_1, k_1) \le F,$$
$$= 1 \quad \text{otherwise.} \qquad ($$

Keeping this in mind, firm 1 maximizes his profit. In other words, his problem is

$$\max_{\{x_1, r_1, k_1\}} \pi_1(x_1, r_1, k_1, D) \quad \text{subject to} \quad (3).$$

This completes our model. It is the solution of this last maximization problem that gives us o equilibrium values of x_1, r_1, k_1 and D. What remains is to illustrate some interesting special cas that can arise within this general framework.

3. Entry deterrence: Automatic and via threat of dumping

Suppose the parameters of our model are specified as follows:

$$p = 10 - (x_1 + x_2), \qquad C_1 = (1 - r_1)x_1 + r_1 \max\{k_1, x_1\}, \qquad C_2 = f_2, \qquad F = 3.5.$$

Given these, it follows that

$$x_2 = R(x_1) = 5 - (x_1/2) \quad \text{if} \quad x_1 < B_1,$$
$$= 0 \quad \text{if} \quad x_1 \ge B_1, \qquad ($$

where

$$B_1 = 10 - 2f_2^{1/2}. \qquad ($$

We now consider two cases.

Case 1. $f_2 = 4$.

In this case, at equilibrium, firm 1 produces its monopoly quantity which is less than B_1, maintai no excess capacity and yet firm 2 does not enter.

All this is easy to check. If $k_1 = 0$ and $D = 0$, then firm 1 maximizes $(10 - x_1)x_1 - x_1$. T maximum occurs at $x_1 = 4.5$ and at this point his profit is 20.25. Suppose he threatens firm 2 [i tells firm 2 that if he enters, firm 1 will produce B_1 which is equal to 6 (see (5))]. What is the cost carrying out this threat?

Using the expression in footnote 2, we see that $\bar{\pi}_1 = 18$. If entry does occur, then, using (2) and (4), we get optimal $x_1 = 6$, $x_2 = 0$ and firm 1's profit is again 18. Thus $\tilde{\pi}_1 = 18$ and $\phi = 0$. Hence the cost of carrying out this threat is zero, i.e., it is a perfect equilibrium (with the post-entry game being Stackelberg with the entrant playing follower). Essentially the threat of limit pricing deters entry.

In this case, firm 1 produces 4.5 units and even though $B_1 = 6$, entry does not occur. On a little reflection this seems obvious enough. Yet in the Dixit–Spence model, firm 1 would have to maintain an excess capacity (i.e., it would set $k_1 = 6$) to deter entry. This is somewhat unrealistic given that even with no excess capacity the net cost of expanding output to 6, should entry occur, is zero. This raises some doubts about the excess capacity hypothesis which argues that $k_1 = B_1$ is necessary to deter entry.

Case 2. $f_2 = \frac{1}{4}$.

In this case, at equilibrium, firm 1 actually produces B_1, though it sells (or supplies) less than that. This is the only way it can deter firm 2's entry and, further, entry-deterrence is its profit-maximising policy.

To see this, first note that, by (8), $B_1 = 9$. Suppose firm 1 sets $k_1 = 9$ and $r_1 = 1(= v_1)$, which in effect means that it actually produces 9 units of the goods. If $D = 1$, then firm 1's maximand is $[5 - (x_1/2)]x_1 - 9$. Hence, firm 1 would produce 5 units and $\tilde{\pi}_1 = 3.5$. Using the expression in footnote 2, we get $\bar{\pi}_1 = 0$. Hence $\phi = 3.5 = F$. Thus only with $r_1 = 1$ and $k_1 = 9$, that is, with *full-commitment* is the threat credible. Having produced 9 units, is it worthwhile selling all 9 units? The answer is no. Having produced 9 units and deterred firm 2's entry, firm 1's maximand is $(10 - x_1)x_1 - 9$. At the optimum, $x_1 = 5$ and profit is 16. [3] Thus it sells 5 units, maintaining the rest (4 units) as inventories – a perennial dumping threat to the potential entrant.

Here the incumbent firm displays characteristics which are a combination of the standard limit-pricing firm and the Spence–Dixit firm carrying excess capacity. The firm produces B_1 units – exactly like the limit-pricing firm, but it does not sell all, thereby maintaining a higher price than the limit-price – exactly as Spence and Dixit suggest.

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[3] It may be checked that had it allowed entry, it would have earned a smaller profit.