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Oligopoly Limit Pricing With Firm-Specific Cost Uncertainty

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Abstract:

Bagwell and Ramey (1991) show that limit pricing does not occur as an equilibrium strategy in oligopoly if entrants are uncertain about an industry cost parameter. I show that if entrants are uncertain about firm-specific cost parameters of oligopoly incumbents, there are pooling equilibria in which incumbents deter entry by high-cost entrants.

I. Introduction

Bagwell and Ramey [1991] model noncooperative entry deterrence in duopoly when incumbents' costs depend on an industry cost parameter. Because incumbents' costs are both high or both low, plausible pooling equilibria fail to exist: in equilibrium, an entrant can infer the true value of the industry cost parameter by observing incumbents' prices.

There are no doubt cases in which one would expect a common industry characteristic to affect all firms' costs in the same way. Examples might be the extraction of oil by different firms from a single oil field or the existence of an industry-wide union wage agreement.¹ But there must be many more cases in which costs, while unknown to an entrant, vary among incumbents on a firm-specific basis. In particular, the case in which a potential entrant contemplates an industry with multiple incumbents, some of which may have high costs while others may have low costs, is surely of interest.

In this paper, I show that if an entrant's uncertainty about incumbents' costs is firm-specific rather than industry specific, then there are conditions under which a sequential equilibrium strategy allows incumbents to deter some entry by producing the outputs that would be produced by low-cost incumbents.

1. It is more difficult to think of examples in which an entrant could not form a reliable estimate of the nature of factors that affected the costs of all firms. A union wage agreement would be observable by potential entrants. Geologists could assess the likely cost of extraction from a given oilfield in a pre-entry period.

II. Duopoly when rival's costs are uncertain

A. A one-period game

I work with a model of quantity-setting oligopoly.² Analysis of duopoly equilibrium in the presence of uncertainty about the rival's cost is a building block for the model of duopoly entry deterrence. In this section, I examine equilibrium in a one-period game.

The inverse demand curve is linear,

$$(1) \quad p = a - Q,$$

(where Q is total output and the assumption that the slope of the demand curve is -1 is not restrictive).

There are two incumbents, 1 and 2. Marginal cost is constant, and takes one of two values. Marginal cost is either high (c_H) or low (c_L). There is nothing essential about the assumption that these values are the same for both firms.

At the start of the first period, each incumbent knows its own marginal cost, but does not know the marginal cost of its rival.

Prior beliefs are described by the probabilities

$$(2a) \quad u_{12} = 1\text{'s prior probability that 2's costs are high;}$$

$$(2b) \quad u_{21} = 2\text{'s prior probability that 1's costs are high.}$$

Prior beliefs are common knowledge. Following Harsanyi [1967-68], this makes it possible to model the game as one of complete but imperfect information with an initial move by nature that endows players with high or low costs with the indicated probabilities.

2. Milgrom and Roberts [1982] consider entry deterrence by a quantity-setting monopolist. Bagwell and Ramey [1991] analyze price-setting duopoly with product differentiation. The difference between Bagwell and Ramey's results and those presented here does not depend on the use of quantity rather than price as a decision variable.

The natural generalization of Cournot equilibrium to the presence of uncertainty is to require that each firm's noncooperative equilibrium output maximize its own expected profit, taking the outputs of rivals of different cost types as given.³ Payoffs are

$$(3a) \quad \pi_{LL} = \{a - c_L - [q_{LL} + (1 - u_{12})q_{2L} + u_{12}q_{2H}]\}q_{LL}$$

$$(3b) \quad \pi_{LH} = \{a - c_H - [q_{LH} + (1 - u_{12})q_{2L} + u_{12}q_{2H}]\}q_{LH}$$

$$(3c) \quad \pi_{2L} = \{a - c_L - [(1 - u_{21})q_{1L} + u_{21}q_{1H} + q_{2L}]\}q_{2L}$$

$$(3d) \quad \pi_{2H} = \{a - c_L - [(1 - u_{21})q_{1L} + u_{21}q_{1H} + q_{2H}]\}q_{2H}$$

The first-order conditions for maximization of these payoffs yield the equations of reaction functions, which vary by firm and by cost type:

$$(4a) \quad 2q_{LL} + (1 - u_{12})q_{2L} + u_{12}q_{2H} = a - c_L$$

$$(4b) \quad 2q_{LH} + (1 - u_{12})q_{2L} + u_{12}q_{2H} = a - c_H$$

$$(4c) \quad (1 - u_{21})q_{1L} + u_{21}q_{1H} + 2q_{2L} = a - c_L$$

$$(4d) \quad (1 - u_{21})q_{1L} + u_{21}q_{1H} + 2q_{2H} = a - c_H$$

Solving the equations of the reaction functions gives equilibrium outputs:

$$(5a) \quad q_{LL} = \frac{1}{3} \left[a - c_L + \frac{2u_{12} - u_{21}}{2}(c_H - c_L) \right],$$

$$(5b) \quad q_{LH} = \frac{1}{3} \left[a - c_H - \frac{1 - 2u_{12} + u_{21}}{2}(c_H - c_L) \right],$$

$$(5c) \quad q_{2L} = \frac{1}{3} \left[a - c_L + \frac{2u_{21} - u_{12}}{2}(c_H - c_L) \right],$$

3. This is the approach of Saloner's [1987] model of duopoly with one-sided uncertainty about firm costs.

$$(5d) \quad q_{2H} = \frac{1}{3} \left[a - c_H - \frac{1 + u_{12} - 2u_{21}}{2}(c_H - c_L) \right].$$

The expected payoff of each type firm is the square of its equilibrium output. (This follows from the equation of the reaction curve and the assumption that the slope of the demand curve is -1.)

B. Pooling equilibrium in a two-period game without the possibility of entry

Now consider a two-period version of the previous model, and suppose that entry is not possible. Here I outline the conditions under which the following is a sequential equilibrium:

- (a) both firms produce $(a - c_L)/3$ in period 1;
- (b) each firm produces its equilibrium output from the one-period game with unknown cost types in period 2;
- (c) firms carry prior beliefs forward from period 1 to period 2.

Out-of-equilibrium beliefs, which are not restricted by the requirement of consistency with Bayes' rule, are such that if a firm observes that its rival produces any output other than $(a - c_L)/3$ in period 1, it concludes that the rival has high cost and maximizes its second-period payoff given this belief.

This pooling equilibrium corresponds to entry-limiting behavior. Exploration of the conditions under which pooling will occur when entry is not possible provides a point of reference for a more general model that allows for the possibility of entry.

If defection leads the rival to conclude that the defecting firm has high cost, a low-cost firm would never defect from such a pooling strategy. $(a - c_L)/3$ is the best-response output of a low-cost duopolist if its rival produces $(a - c_L)/3$. Defection would reduce the defecting firm's payoff in the first period and induce the rival

to expand output in the second period,⁴ reducing the defector's second-period payoff as well.

If firm 1H follows the pooling strategy, its expected first-period payoff is

$$(6) \quad \begin{aligned} & [a - c_H - \frac{2}{3}(a - c_L)](a - c_L)/3 \\ &= \frac{1}{9} \left[a - c_H - \frac{1}{2}(c_H - c_L) \right]^2 - \frac{1}{4}(c_H - c_L)^2. \end{aligned}$$

Its expected second period payoff if it adheres to the pooling strategy is the square of equilibrium output from the one-period game with unknown cost types, given by equation (5b). Its payoff for the game, ignoring discounting, is the sum of its payoffs over the two periods.

If firm 1H defects, it reveals that it has high cost. A defecting firm 1H will therefore produce a first-period output that is its best response to the equilibrium output $(a - c_L)/3$ of firm 2. The resulting first-period payoff is

$$(7) \quad \frac{1}{9} \left[a - c_H - \frac{1}{2}(c_H - c_L) \right]^2$$

When firm 1H sets its second-period output, it does not know firm 2's cost type. The output that maximizes firm 1H's expected second period payoff, found by solving the system of equations formed by the reaction functions of firms 1H, 2L, and 2H, is

4. The difference between firm 1L's second period payoff if it follows the pooling strategy and its payoff if it defects in the first period is

$$\frac{1}{2}(1 - u_{21})(c_H - c_L)(*) ,$$

where (*), the sum of firm 1L's second period outputs if it follows and if it defects from the equilibrium strategy, is positive. Unless the rival's prior belief is that firm 1L has high cost with probability 1, firm 1H earns a greater second-period payoff by following the equilibrium strategy.

$$(8) \quad \frac{1}{3}[a - c_H - (1 - u_{12})(c_H - c_L)] .$$

Its expected second-period payoff is the square of this output.

Comparing adherence and defection payoffs, firm 1H will follow the pooling strategy if

$$(9) \quad \frac{1}{9}(1 - u_{21}) \left[a - c_H - \frac{3 - 4u_{12} + u_{21}}{4}(c_H - c_L) \right] \geq \frac{1}{4}(c_H - c_L) .$$

Evidently, this condition fails if u_{21} is sufficiently near 1. If firm 2 is convinced that firm 1 has high cost, firm 1H is better off defecting from a pooling strategy. But the left-hand side of (9) is larger as u_{12} is larger. It is more in firm 1H's interest to conceal its cost type if it believes firm 2 has high costs.

A condition corresponding to (9) must be met if firm 2H is to adhere to the pooling strategy. Adherence by firm 2H is more likely, the smaller is u_{12} and the larger is u_{21} , just opposite the conditions on prior beliefs that make adherence by firm 1H likely. To show that there is a range of beliefs for which both firm 1H and firm 2H will follow this pooling strategy, I turn to the symmetric beliefs case. If $u_{12} = u_{21} = u$, (9) becomes

$$(10) \quad a - c_H \geq \left[1 - u + \frac{3}{1 - u} \right] \frac{3}{4}(c_H - c_L) .$$

As expected from (9), (10) fails if u is sufficiently near 1. As u goes to 0, (10) becomes

$$(11) \quad a - c_H \geq 3(c_H - c_L) .$$

Hence if the cost disadvantage of high-cost firms is not too great and if firms are not too certain that their rivals have high costs, the pooling strategy described above will be a sequential equilibrium.

An Example

Suppose $a = 10$, $c_L = 1$, $c_H = 2$, $u_{12} = 0.4$, and $u_{21} = 0.6$. Then Firm 1H earns a payoff of 12.41 if it follows the pooling strategy, while its defection payoff is 12.33. Firm 2H earns a payoff 12.93 if it pools, and 12.66 if it defects. The condition (9) is $0.33 > 0.25$ for firm 1H and $0.52 > 0.25$ for firm 2H. For these parameter values, high-cost firms earn greater payoffs by pooling in the first period.

III. Pooling equilibrium in a two-period game with entry

A. Structure of the game

Now modify the two-period game considered above by supposing that there is a single entrant (E) who observes first period outputs before deciding whether or not to enter, who must pay a sunk entry cost $K > 0$ to come into the market, and who breaks even by staying out of the market. The potential entrant's costs are either high or low and are known to the entrant but not to the incumbents.

Prior beliefs are given by the probabilities

(12a) u = incumbent i 's prior probability that incumbent j 's costs are high, $i, j = 1, 2, i \neq j$;

(12b) v = incumbents' prior probability that entrant's costs are high;

(12c) w = entrant's prior probability that incumbent i 's costs are high, $i = 1, 2$.

For simplicity I have imposed a limited symmetry of beliefs. This part of the specification can be relaxed without altering the nature of the results. Prior beliefs are common knowledge.

B. A precondition for entry limitation

To determine conditions under which it is possible for incumbents to pool output in the first period and limit the entry of high-cost entrants, it is first necessary to determine equilibrium payoffs from

the game played in the second period if entry occurs but each firm knows only its own cost type. In such a game, each firm of each cost type maximizes its expected profit. That of a low-cost firm 1, for example, is

$$(13) \pi_{1L} = \{a - c_L - [q_{1L} + (1 - u)q_{2L} + uq_{2H} + (1 - v)q_{1E} + vq_{1H}]\}q_{1L}$$

The first-order conditions for the maximization of expected profit by three firms, of two cost types each, can be solved for equilibrium outputs. The equilibrium outputs of low-cost and high-cost entrants are

$$(14a) \quad q_{1E} = \frac{1}{4}[a - c_L - (u + v - 3w)(c_H - c_L)]$$

$$(14b) \quad q_{1H} = \frac{1}{4}[a - c_H - (1 + u + v - 3w)(c_H - c_L)]$$

respectively. Expected payoffs are the squares of equilibrium outputs, less sunk costs of entry K .

The expected profit of a low-cost entrant exceeds the expected profit of a high-cost entrant. If a low-cost entrant's expected profit from entry is negative, then incumbents can preclude all entry by pooling in the first period. If a high-cost entrant's expected profit is positive, then incumbents cannot limit entry. The intermediate case is that in which a low-cost entrant expects a positive profit, but a high-cost entrant a negative profit. This occurs if

$$(15) \quad \begin{aligned} a - c_L - (u + v - 3w)(c_H - c_L) &\geq 4\sqrt{K} \\ &> a - c_L - (2 + u + v - 3w)(c_H - c_L), \end{aligned}$$

a condition I henceforth assume is met. It is then possible for incumbents to limit the entry by high-cost entrants. I now outline conditions under which incumbents will engage in such behavior as an equilibrium strategy.

C. Equilibrium oligopoly limit pricing

Structure of the equilibrium pooling strategy

I investigate a pooling entry-limiting sequential equilibrium

with the following characteristics:

- (a) incumbent duopolists each produce $(a - c_L)/3$ in period 1;
- (b) a high-cost entrant stays out in period 2;
- (c) a low-cost entrant comes in in period 2;
- (d) if entry does not occur, incumbents produce the appropriate outputs from (5);
- (e) if entry occurs, the entrant is revealed as having low-cost, while incumbents' cost types are unknown except to themselves. Each player produces the second-period output that maximizes its expected payoff, given prior beliefs;
- (f) incumbents and the low-cost entrant carry prior beliefs forward from the first to the second period.

Out-of-equilibrium beliefs are not restricted by the requirements of sequential equilibrium. I assume that if an incumbent produces any output other than $(a - c_L)/3$ in period 1, its rivals conclude that the defecting firm has high cost. Incumbents' payoffs are the sum of their payoffs in the two periods.

Second period equilibrium payoffs

If the pooling strategy is followed, entry will occur only if the entrant has low cost. Incumbents' prior probability for this is $(1 - v)$. Hence if the pooling strategy is followed, incumbents expect entry to occur with probability $1 - v$.

If entry occurs, the entrant is revealed as having low cost, but an incumbent's cost type is known only to itself. Equilibrium outputs are found by solving the system of 5 equations given by the reaction functions of the entrant and incumbents 1L, 1H, 2L, 2H, and EL. They are

$$(16a) \quad q_{1L} = q_{2L} = \frac{1}{4}[a - c_L + (u - w)(c_H - c_L)]$$

$$(16b) \quad q_{1H} = q_{2H} = \frac{1}{4}[a - c_H - (1 - u + w)(c_H - c_L)]$$

$$(16c) \quad q_{EL} = \frac{1}{4}[a - c_L + (u - 3w)(c_H - c_L)] .$$

An incumbent's expected payoff is the square of its output. The low-cost entrant's expected payoff is the square of its output, less sunk entry cost K .

The entrant's output, and therefore payoff, in this 5-player game exceeds equilibrium output (14a) of the low-cost entrant in the 6-player game treated above. Condition (15) therefore implies that output (16c) yields the low-cost entrant a positive expected profit.

If entry does not occur, an event which incumbents regard as having probability v , incumbents' expected second-period payoffs are those of the one-period game with unknown cost types (using (5) and (12))

$$(17a) \quad \pi_{1L} = \pi_{2L} = \frac{1}{9}[a - c_L + \frac{u}{2}(c_H - c_L)]^2$$

$$(17b) \quad \pi_{1H} = \pi_{2H} = \frac{1}{9}[a - c_H - \frac{1}{2} - \frac{u}{2}(c_H - c_L)]^2 .$$

Behavior of the entrant

In equilibrium, the entrant acquires no information about incumbents' cost types by observing first-period output. The alleged equilibrium strategy calls for the potential entrant to come in if expected profit from entry is positive, and otherwise to stay out. Given its beliefs, the entrant maximizes its expected payoff by behaving in this way.

Behavior of low-cost incumbents

If a low-cost incumbent produces any output other than $(a - c_L)/3$ in period 1, it reduces its expected first-period payoff and portrays itself as a high-cost firm to the other incumbent and to the entrant. This induces the other incumbent to produce more output in period 2

than if the equilibrium strategy were followed. It does not reduce, and may increase, the probability of entry. First-period defection therefore reduces the expected second-period payoff as well as the expected first-period payoff. It follows that a low-cost incumbent would never defect from the strategy outlined above.

Behavior of high-cost incumbents

A high-cost incumbent's expected payoff from adhering to the alleged sequential equilibrium strategy is

$$(18) \quad \frac{1}{9}[a - c_H - \frac{1}{2}(c_H - c_L)]^2 - \frac{1}{4}(c_H - c_L)^2 + \frac{v}{9}\left[a - c_H - \frac{1-u}{2}(c_H - c_L)\right]^2 + \frac{1-v}{16}\left[a - c_H - (1-u+w)(c_H - c_L)\right]^2.$$

where the first two terms give the first-period payoff and the final two terms are the expected second-period payoff.

Given the nature of out-of-equilibrium beliefs, if firm 1H defects it will produce an output that maximizes its first-period payoff. The resulting defection payoff in the first period is

$$(19) \quad \frac{1}{9}[a - c_H - \frac{1}{2}(c_H - c_L)]^2.$$

By defecting, firm 1H reveals itself as a high-cost firm. It is no longer certain that a high-cost entrant will stay out in the second period. To evaluate second-period payoffs, two cases must be considered.

H incumbent defection does not make EH entry profitable

Suppose first that a single high-cost firm could defect without making it profitable for a high-cost entrant to come into the market. A condition for this to occur is given in the following section. At the time firm 1H decides whether or not it will defect from the equilibrium strategy, it has before it 2 alternative second-period

scenarios. If it defects, it reveals itself as having high cost. With probability v the potential entrant has high cost and stays out of the market in the second-period. Second-period outputs are determined by solving the equations of the reaction functions for firms 1H, 2L, and 2H:

$$(20a) \quad 2q_{1H} + (1 - u)q_{2L} + uq_{2H} = a - c_H$$

$$(20b) \quad q_{1H} + 2q_{2L} = a - c_L$$

$$(20c) \quad q_{1H} + 2q_{2H} = a - c_H.$$

Solving this system of equations, firm 1H's second-period output if entry does not occur after defection is

$$(21) \quad \frac{1}{3}[a - c_H - (1 - u)(c_H - c_L)].$$

Its second-period payoff in this case is the square of its output.

With probability $1 - v$, the entrant has low cost and will come into the market in the second period. Second period outputs are determined by the reaction functions for firms 1H, 2L, 2H, and EL:

$$(22a) \quad 2q_{1H} + (1 - u)q_{2L} + uq_{2H} + q_{EL} = a - c_H$$

$$(22b) \quad q_{1H} + 2q_{2L} + q_{EL} = a - c_L$$

$$(22c) \quad q_{1H} + 2q_{2H} + q_{EL} = a - c_H$$

$$(22d) \quad q_{1H} + (1 - w)q_{2L} + wq_{2H} + 2q_{EL} = a - c_L.$$

In entry occurs, firm 1H's post-entry output is

$$(23) \quad \frac{1}{4} \left[a - c_H - \frac{4 - 3u + w}{2}(c_H - c_L) \right],$$

and its second-period expected payoff is the square of this output.

Firm 1H's expected payoff if it defects from the strategy is

$$(24) \quad \frac{1}{9} \left[a - c_H - \frac{1}{2}(c_H - c_L) \right]^2 + \frac{v}{9} [a - c_H - (2 - u)(c_H - c_L)]^2 \\ + \frac{1 - v}{16} \left[a - c_L - \frac{4 - 3u + w}{2}(c_H - c_L) \right]^2.$$

If firm 1H adheres to the pooling strategy, on the other hand, its expected payoff is given by (18). Comparing (18) and (24), firm 1H will earn at least as great a payoff by adhering to the pooling strategy as by defecting if

$$(25) \quad \frac{1-v}{16} \left[a - c_H - \frac{6-5u+3w}{4} (c_H - c_L) \right] (2-u-w) \\ + \frac{v}{9} (1-u) \left[a - c_H - 3(1-u) \frac{c_H - c_L}{4} \right] \geq \frac{1}{4} (c_H - c_L).$$

If $v = 1$, the first term on the left vanishes. If firm 1H believes the entrant has high cost, it believes that entry will not occur. The loss of profit on defection is expected to come from revealing to firm 2 that firm 1 has high cost. This explains the similarity between the left-hand side of (9) and the second term in (25).

If $u = 1$, the second term on the left vanishes. If firm 2 believes that firm 1 has high cost, then firm 1H's defection from the equilibrium strategy provides firm 2 with no new information. The loss of profit on defection is expected to come from revealing to the entrant that firm 1 has high cost.

H incumbent defection makes EH entry profitable

If a high-cost entrant would come into the market, knowing that one incumbent has high cost, then the fact of entry does not reveal the entrant's cost type. Second-period outputs are found by solving the equations of reaction curves for firms 1H, 2L, 2H, EL, and EH. The resulting equilibrium outputs are

$$(26a) \quad q_{1H}^{d2} = \frac{1}{4} \left[a - c_H - \frac{4-3u-2v+w}{2} (c_H - c_L) \right]$$

$$(26b) \quad q_{2L}^{d2} = \frac{1}{4} \left[a - c_L + \frac{2-u+2v-w}{2} (c_H - c_L) \right]$$

$$(26c) \quad q_{2H}^{d2} = \frac{1}{4} \left[a - c_H - \frac{u-2v+w}{2} (c_H - c_L) \right]$$

$$(26d) \quad q_{EL}^{d2} = \frac{1}{4} \left[a - c_L + \frac{2 - u - 2v + 3w}{2} (c_H - c_L) \right]$$

$$(26e) \quad q_{EH}^{d2} = \frac{1}{4} \left[a - c_H - \frac{u + 2v - 3w}{2} (c_H - c_L) \right].$$

The condition for defection to induce entry by a high-cost potential entrant is that such an entrant expect a nonnegative payoff after entry. From (26e), this will be the case if

$$(27) \quad a - c_H - \frac{u + 2v - 3w}{2} (c_H - c_L) \geq 4\sqrt{K}.$$

If inequality (27) is not met, then the defection payoff is given by (24) and the analysis of the previous section applies. If (27) holds, firm 1H's defection payoff is

$$(28) \frac{1}{9} \left[a - c_H - \frac{1}{2} (c_H - c_L) \right]^2 + \frac{1}{16} \left[a - c_H - \frac{4 - 3u - 2v + w}{2} (c_H - c_L) \right]^2$$

Comparing (18) and (28), when defection leads a high-cost entrant to come into the market, firm 1H will prefer to follow the sequential equilibrium strategy if

$$(29) \quad \begin{aligned} & v \left(\frac{1}{9} - \frac{1}{16} \right) \left[a - c_H - \frac{4 - 3u - 2v + w}{2} (c_H - c_L) \right]^2 \\ & + \frac{1 - v}{16} \left[a - c_H - \frac{5 - 5u - 2v + 3w}{4} (c_H - c_L) \right] (2 - u - 2v - w) (c_H - c_L) \\ & + \frac{v}{9} \left[a - c_H - \frac{5 - 4u - 2v + w}{4} (c_H - c_L) \right] (3 - 2u - 2v + w) (c_H - c_L) \\ & \geq \frac{1}{4} (c_H - c_L)^2 \end{aligned}$$

The first term on the left reflects the expected loss of profit if the entrant has high cost and comes into the market in the knowledge that at least one of the incumbents has high cost. This term makes it more likely that high-cost incumbents will be willing to pool in the first period, and it appears precisely because there is some probability that pooling in the first period will deter entry in the second period.

Observe further that if $v = 0$, conditions (25) and (29) are identical. If incumbents believe that the potential entrant has low cost with probability 1, their incentives to pool are unrelated to the decisions that a high-cost entrant would make. If $v = 1$, high-cost incumbents will pool if they earn a sufficiently greater payoff in the second period by keeping their cost types hidden.

Examples

Let $a = 10$, $u = 0.4$, $v = 0.5$, and $w = 0.6$. In a 6-player game with unknown cost types, entrants outputs would be $q_{EL} = 2.475$ and $q_{EH} = 1.975$. For any entry cost less than 3.9, a high-cost entrant would come into the market against incumbents of unknown cost types. Entry limitation would therefore be impossible. For entry costs greater than 6.125, even a low-cost entry would stay out against incumbents of unknown cost types.

Suppose entry cost $K = 4$. If a high-cost firm defects in the first period, and a high-cost entrant would produce output 2.3 in the second period and expect a profit 1.29. Defection by a high-cost incumbent would therefore induce entry by a high-cost entrant. A high-cost incumbent's payoff if it pools in the first period is 10.73, while defection brings it only 9.14.

If on the other hand $K = 6$, a high-cost entrant would stay out of the market even if defection were to reveal that one of the incumbents had high cost. A high-cost incumbent's payoff if follows the pooling strategy is again 10.73, against 10.53 if it defects.

IV. Conclusion

Limit pricing fails as an equilibrium strategy in Bagwell and Ramey (1991) because the entry decision depends on an industry-wide cost parameter and firms cannot noncooperatively coordinate deception.

In the model developed here, the entry decision depends on firm-specific cost parameters, and limit pricing may emerge as a sequential equilibrium oligopoly strategy. Part of the incentive to adhere to such a strategy is the second-period profit that is expected to be preserved if entry is deterred.

Two conclusions may be drawn. First, where uncertainty about costs is firm-specific rather than industry-specific, oligopolistic entry deterrence is a possibility. Second, the likelihood that such a strategy will emerge as a noncooperative equilibrium falls as the number of incumbents rises, since the expected saving in profit from deterring entry falls, the larger the number of incumbents.⁵

5. This can be shown formally by generalizing the model presented here to allow for $n > 2$ incumbents.

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