Chapter 12: Limit Pricing and Entry Deterrence

Learning Objectives:

Students should learn to:

1. Define and give examples of predatory conduct.
2. Explain stylized facts about the entry of firms into industries.
3. Define and use the concept of residual demand and residual inverse demand.
4. Graphically analyze a market model with a Stackelberg leader practicing limit pricing.
    a. Incumbent firm is a Stackelberg leader who chooses a fixed level of output
    b. Potential entrant believes that his/her output decision will not affect the level of output chosen by the leader
    c. Entrant's average cost curve is declining in the relevant region
    d. Entrant firm optimizes by setting residual marginal revenue equal to marginal cost, taking the quantity supplied by the leader firm as given
    e. Dominant firm takes behavior of entrant into consideration in setting its output level, setting output such that the entrant will have zero profit if it enters
5. Algebraically analyze a simple market model (linear demand) where the incumbent (Stackelberg leader) practices limit pricing.
6. Compare the potential returns from predation and from merger and analyze the incentives for particular types of strategies in different markets.
7. Explain the difference between a simultaneous and sequential game. The student will be able to explain and utilize the concept of sub-game perfection in solving extensive form games.
8. Utilize backward induction to solve extensive form games. The student will be able to prune extensive form game trees as a means for backward induction.
9. The student will be able to intuitively explain why capacity serves as a mechanism demonstrating commitment. The student will be able to solve simple extensive form games involving capacity expansion by incumbent firms when the data on costs and returns is given.
10. The student will be able to use the Dixit model to determine the costs and returns to an incumbent and an entrant when the marginal cost of production is endogenous and depends on the choice of capacity in the first period of a two-period model.
11. The student will be able to explain the importance of sunk entry costs in Dixit-type models, show how such costs affect the actions of an incumbent firm, and use such models to determine the initial investment of an incumbent.
12. The student will be able to relate economies of scale to cases of preemption by an incumbent firm.
13. The student will be able to expand the model to limit pricing to cases where the entrant does not know the cost structure of the incumbent and makes decisions based on expected profits.

Suggested Lecture Outline:

Spend three fifty-minute long lectures on this chapter.

Lecture 1:

1. examples of monopolies or near monopolies
2. predatory conduct and credible threats
3. stylized facts about entry
   incumbent firms, residual demand curves, and entrant firms
4. limit pricing in incumbent/entrant (Stackelberg) models
5. predation in incumbent/entrant (Stackelberg) models

Lecture 2:

1. extensive form games
2. subgames in extensive form games and subgame perfection
3. representing simultaneous games in normal and extensive form
4. limit pricing
5. capacity expansion as a form of credible commitment

Lecture 3:

1. blockading entry versus impeding entry
2. overinvestment in capacity as a means to insure credibility
3. preemption when there are significant economies of scale
4. uncertainty in the limit pricing model
5. numerical examples / problems on Limit Pricing and Entry Deterrence

Suggestions for the Instructor:

1. One should work through (or have the students work through) both a numerical and a graphical incumbent/entrant firm model.
2. It is easiest to explain subgame perfection using extensive form games and game trees. The idea of pruning a branch is intuitive to the students and leaves them with a smaller and simpler tree.
3. It may be very helpful to give the students a handout like the box entitled “The Calculus of Predation: Limit Pricing, Limit Output, and Capacity Constraints” with a numerical example.

Solutions to End of the Chapter Problems:

Problem 1

(a) Setting marginal revenue equal to marginal cost will yield

$$MR = 50 - 0.2\,q_I = 0.05 q_I = MC$$
$$\rightarrow 0.25 q_I = 50$$
$$\rightarrow q_I = 200$$
$$\Rightarrow P = 50 - 0.1 q_I$$
$$= 50 - 20$$
$$= 30$$

The firm will have profits equal to

$$\pi_I = (30)(200) - (0.025)(200)^2$$
$$= 6{,}000 - 1{,}000 = 5{,}000$$

(b) The industry demand curve can be written as

$$P = 50 - 0.1\,Q$$
$$= 50 - 0.1 q_I - 0.1 q_E$$
$$= 50 - (0.1)(200) - 0.1 q_E$$
$$= 30 - 0.1 q_E$$

Marginal revenue for the entrant firm will be

$$MR_E = 30 - 0.2 q_E$$

Setting marginal revenue equal to marginal cost we obtain

$$MR_E = 30 - 0.2 q_E = 10 + 0.05 q_E = MC_E$$
$$\Rightarrow 0.25 q_E = 20$$
$$\rightarrow q_E = 80$$
$$\rightarrow P = 50 - (0.1)(200) - (0.1)(80)$$
$$= 50 - 20 - 8$$
$$= 22$$

The entrant will export 80 units to the market and price will fall from \$30 to \$22. The total quantity transacted will rise from 200 to 280. Profits for the two firms will be

$$\pi_I = (22)(200) - (0.025)(200)^2$$
$$= 4{,}400 - 1{,}000 = 3{,}400$$
$$\pi_E = (22)(80) - (10)(80) - (0.025)(80)^2$$
$$= 1{,}760 - 800 - 160 = 800$$

(c) We simply need to find the level of $q_1 = Q$ such that the best response of the entrant is to produce zero output. Writing the residual demand curve as a function of q_I we obtain

$$P = 50 - 0.1\,Q$$
$$= 50 - 0.1 q_I - 0.1 q_E$$

Marginal revenue for the entrant firm will be

$$MR_E = 50 - 0.1 q_I - 0.2 q_E$$

Setting marginal revenue equal to marginal cost we obtain

$$MR_E = 50 - 0.1q_I - 0.2q_E = 10 + 0.05q_E = MC_E$$
$$\Rightarrow 0.25q_E = 40 - 0.1q_I$$
$$\Rightarrow q_E = 160 - 0.4q_I$$

If the incumbent chooses q_I such that the optimal $q_E = 0$, the entrant will not enter. This implies

$$q_E = 160 - 0.4q_I = 0$$
$$\rightarrow 0.4q_I = 160$$
$$\rightarrow q_I = 400$$
$$\Rightarrow \underline{Q} = 400$$

With this level of output price and profits for the two firms are

$$\begin{aligned} P &= 50 - 0.1q_I - 0.1q_E \\ &= 50 - (0.1)(400) - (0.1)(0) \\ &= 50 - 40 \\ &= 10 \\ \pi_I &= (10)(400) - (0.025)(400)^2 \\ &= 4{,}000 - 4{,}000 = 0 \\ \pi_E &= (10)(0) - (10)(0) - (0.025)(0)^2 \\ &= 0 \end{aligned}$$

If the incumbent were to produce not 400 units, but instead 350 units, then the optimal response of the entrant would be to produce 20 units. This is clear from the response equation

$$\begin{aligned} q_E &= 160 - 0.4q_I \\ &= 160 - 0.4(350) = 160 - 140 \\ &= 20 \\ \Rightarrow P &= 50 - (0.1)(350) - (0.1)(20) \\ &= 13 \\ \pi_I &= (13)(350) - (0.025)(350)^2 \\ &= 4{,}550 - 3{,}062.5 = 1{,}487.5 \\ \pi_E &= (13)(20) - (10)(20) - (0.025)(20)^2 \\ &= 260 - 200 - 10 \\ &= 50 \end{aligned}$$

Problem 2

Now consider a two-firm Cournot model with different cost functions for each firm. The solution is obtained by choosing q_i to maximize profit given the rival's output. For firm 1:

$$\begin{aligned} \pi_I &= [Pq_I - C(q_I)] \\ &= [(50 - 0.1q_I - 0.1q_E)q_I - 0.025q_I^2] \\ &= [50q_I - 0.1q_I^2 - 0.1q_Iq_E - 0.025q_I^2] \end{aligned}$$

$$\Rightarrow \frac{d\pi_I}{dq_I} = 50 - 0.2q_I - 0.1q_E - 0.05q_I = 0$$
$$\rightarrow 0.25q_I = 50 - 0.1q_E$$
$$\Rightarrow q_I^* = 200 - 0.4q_E$$

Similarly, the best response function for the second firm is given by

$$\begin{aligned}
\pi_E &= [Pq_E - C(q_E)] \\
&= [(50 - 0.1q_I - 0.1q_E)q_E - 10q_E - 0.025q_E^2] \\
&= [50q_E - 0.1q_Iq_E - 0.1q_E^2 - 10q_E - 0.025q_E^2]
\end{aligned}$$

$$\begin{aligned}
\rightarrow \frac{d\pi_E}{dq_E} &= 50 - 0.1q_I - 0.2q_E - 10 - 0.05q_E = 0 \\
\Rightarrow 0.25q_E &= 40 - 0.1q_I \\
\rightarrow q_E^* &= 160 - 0.4q_I
\end{aligned} \tag{74}$$

We solve for the optimal q_i* simultaneously as follows

$$\begin{aligned}
q_E &= 160 - 0.4q_I \\
&= 160 - 0.4(200 - 0.4q_E) \\
&= 160 - 80 + 0.16q_E \\
&= 80 + 0.16q_E \\
\Rightarrow 0.84q_E &= 80 \\
\Rightarrow q_E &= 95.238
\end{aligned}$$

$$\begin{aligned}
q_I &= 200 - 0.4q_E \\
&= 200 - 0.4(95.238) \\
&= 200 - 38.095 \\
&= 161.90476
\end{aligned}$$

Price is given by

$$\begin{aligned}
P &= 50 - 0.1\,Q \\
&= 50 - 0.1q_I - 0.1q_E \\
&= 50 - (0.1)(161.90476) - (0.1)(95.23809) \\
&= 24.285715
\end{aligned}$$

Profits are given by

$$\begin{aligned}
\pi_I &= (24.2857)(161.9047) - (0.025)(161.9047)^2 \\
&= 3{,}931.973 - 655.329 = 3{,}276.644 \\
\pi_E &= (24.2857)(95.23809) - (10)(95.23809) - (0.025)(95.23809)^2 \\
&= 2{,}312.925 - 952.381 - 226.757 \\
&= 1{,}133.787
\end{aligned}$$

The incumbent earns a profit less than if he maintains the monopoly output and the entrant produces 80 units. However, $q_I = 200$ is not optimal if the entrant produces 80 units as

$$\begin{aligned}
q_I &= 200 - 0.4q_E \\
&= 200 - (0.4)(80) \\
&= 168
\end{aligned}$$

which of course is not 200 so the threat is not credible.

Problems 3 and 4

Similar to Practice Problem 12.2.

Problem 5

Firm 1 enters and chooses a small size. Firm 2 enters afterwards and chooses a small size as well.

Problem 6

(a) Write the market demand curve in inverse form as follows

$$q = \sum_{j=1}^{1,000} q_j = 70,000 - 2,000P$$
$$\Rightarrow 2,000P = 70,000 - \sum_{j=1}^{1,000} q_j$$
$$\rightarrow P = 35 - (0.0005)\sum_{j=1}^{1,000} q_j$$

Now consider marginal cost for the first firm and set it equal to price (firms are price takers)

$$MC(q_1) = q_1 + 5 = 35 - (0.0005)q_1 - (0.0005)\sum_{j\neq 1}^{1,000} q_j$$
$$\Rightarrow 1.0005q_1 = 30 - (0.0005)\sum_{j\neq 1}^{1,000} q_j$$
$$\Rightarrow q_1 = 29.985007 - (0.00049975012)\sum_{j\neq 1}^{1,000} q_j$$

Since the firms are all the same we can substitute for q_j with q_1 to obtain

$$q_1 = 29.985007 - (0.00049975012)\sum_{j\neq 1}^{1,000} q_j$$
$$\Rightarrow q_1 = 29.985007 - (0.00049975012)\sum_{j\neq 1}^{1,000} q_1$$
$$\Rightarrow q_1 = 29.985007 - (0.00049975012)(999)q_1$$
$$q_1 = 29.985007 - 0.4992503q_1$$
$$\rightarrow 1.49975012q_1 = 29.985007$$
$$\Rightarrow q_1 = 20$$

This implies that q = 20,000 and p = MC = 25.

We can also find this by horizontally adding the marginal cost functions and then setting supply equal to demand as follows

$$MC(q_i) = q_i + 5$$
$$\Rightarrow q_i = MC(q_i) - 5$$
$$\Rightarrow 1,000q_i = q = 1,000MC(q_i) - 5,000$$
$$\Rightarrow 1,000MC(q_i) = q + 5,000$$
$$\Rightarrow MC(q_i) = 0.001q + 5$$

Setting this equal to price from above we obtain

$$MC(q_i) = 0.001q + 5 = 35 - 0.0005q = P$$
$$\Rightarrow 0.0015q = 30$$
$$\rightarrow q = 20{,}000$$
$$\Rightarrow q_i = 20$$

We can also write the marginal cost relation in quantity dependent form (the normal supply curve) and then set supply equal to demand as

$$P = 0.001q + 5$$
$$\Rightarrow q = 1{,}000P - 5{,}000$$

$$q = 1{,}000P - 5{,}000 = 70{,}000 - 2{,}000P = q$$
$$\Rightarrow 3{,}000P = 75{,}000$$
$$\Rightarrow P = 25$$
$$\Rightarrow q = 20{,}000$$

(b) Denote supply by the small sellers as q_F and demand for the product of the BIG firm as q_B, with total demand given by q_T. The residual supply curve for the small sellers is given by

$$q_F = 1{,}000P - 5{,}000$$

Then we have as residual demand for the BIG firm

$$q_T = q_B + q_F = 70{,}000 - 2{,}000P$$
$$\Rightarrow q_B = 70{,}000 - q_F - 2{,}000P$$
$$= 70{,}000 - (1{,}000P - 5{,}000) - 2{,}000P$$
$$= 75{,}000 - 3{,}000P.$$

Residual inverse demand is found by inverting the residual demand function as follows

$$q_B = 75{,}000 - 3{,}000P$$
$$\Rightarrow 3{,}000P = 75{,}000 - q_B$$
$$\Rightarrow P = 25 - \frac{1}{3{,}000}q_B$$

(c) Profit for BIG is given by

$$\pi_B = Pq_B - 15q_B$$
$$= (25 - \frac{1}{3{,}000}q_B)q_B - 15q_B$$
$$= 25q_B - \frac{1}{3{,}000}q_B^2 - 15q_B$$
$$= 10q_B - \frac{1}{3{,}000}q_B^2$$

$$\frac{d\pi_B}{dq_B} = 10 - \frac{2}{3{,}000}q_B = 0$$
$$\Rightarrow \frac{2}{3{,}000}q_B = 10$$
$$\Rightarrow q_B = 15{,}000$$
$$\Rightarrow P = 25 - \frac{1}{3{,}000}(15{,}000)$$
$$= 25 - 5$$
$$= 20$$

The residual firms then supply

$$\begin{aligned} q_F &= 1{,}000P - 5{,}000 \\ &= (1{,}000)(20) - 5{,}000 \\ &= 15{,}000 \end{aligned}$$

Total quantity supplied is then q_T = 30,000. This comes from adding q_B and q_F or by plugging price in the original as opposed to the residual demand curve

$$\begin{aligned} q_T &= q_B + \sum_{j=1}^{1{,}000} q_j = 70{,}000 - 2{,}000(20) \\ &= 70{,}000 - 40{,}000 \\ &= 30{,}000 \end{aligned}$$

7. Throughout, we assume that $0 < r < 1$. It is easy to see that $t_1 = t_2 = 1/2$ is a Nash equilibrium. Suppose that $t_2 = 1/2$. If firm 1 choose a time $t_1 = 1/2$, its profit is simply $\pi^1 = e^{0.5(1-r)}$. If instead, it chooses $t_1 < 1/2 - U$, then its profit is $\pi^1 = e^{0.5(1-r)-(1-r)U} < e^{0.5(1-r)}$. Similarly, if it chooses $t_1 = 1/2 + U$ its profit is $\pi^1 = e^{0.5(1-r)-rU} < e^{0.5(1-r)}$. Thus, $t_1 = 1/2$ is a best response to $t_2 = 1/2$. Since the problem is symmetric, $t_1 = t_2 = 1/2$, is a pair of best responses and, hence, a Nash Equilibrium. To see that it is a unique Nash Equilibrium, first suppose t_2 is an arbitrarily small amount ε from 0. If firm 1 matches firm 2, it will then earn: $\pi^1 = e^{0.5-r\varepsilon}$. However, if it waits a short time U longer, it will then earn: $\pi^1 = e^{(1-\varepsilon)-rU}$, which is greater than $\pi^1 = e^{0.5-r\varepsilon}$ when $t_2 = \varepsilon < 1/2$. Likewise, for any value $t_2 > ½$, firm 1 always does better by going a little bit faster, i.e., by setting $t_1 < t_2$.