require that the actions taken by a firm are profitable *only if* they drive existing rivals out of the market or deter potential rivals from coming in to the market.

To put it somewhat loosely, predatory conduct must appear on the surface to reduce the predator firm's profit and seem to be "irrational." The rationality for such conduct would be the additional profit the predator earns *if and only if* the conduct is successful at limiting the competition.

When the "irrational" or predatory action in question is the firm's setting an ultra-low price that drives rival firms out of business it is called *predatory pricing*. Historically, accusations of such predatory pricing are among the most common cases of alleged predation. However, setting a low price that instead deters potential rivals from entering the market in the first place can also be predatory. The entry-limiting price is typically referred to as the *limit price*. If output is the strategic variable, we will refer to the analogous entry-deterring output as the *limit output*. We start the important work of this chapter by reviewing two approaches to limit pricing. The first one is an earlier approach predating the advent of a game theoretic treatment of the subject. The second approach takes the insight of the first but derives a more fundamental explanation of such entry deterrence rooted in a dynamic game between the incumbent and the entrant.

12.2.1 An Informal Model of Entry Deterrence

The traditional limit-pricing story of entry deterrence is told in the work of Bain (1956) and later modeled in Sylos-Labini (1962). These earlier industrial organization economists were shrewd observers of everyday business practices and had reasons to believe that predatory pricing and entry-deterring behavior occurred. We can illustrate the essence of the limit pricing strategy using a simple variant of the Stackelberg model. Recall from the previous chapter that the strategic variable in the Stackelberg model is quantity. So, the analysis we present might more properly be labeled a limit output model, rather than a limit price one. Yet the basic idea of setting the strategic variable so as to deter entry is the same in either case—especially because the dominant firm's output choice will greatly influence the industry price. That is, we might regard the resulting price in our model as the limit price.

Figure 12.1 illustrates the essential features of the model. The incumbent firm is the Stackelberg leader and is allowed to choose its output first. We begin by making a simple and yet strong assumption that whatever this choice is, the entrant believes that its own entry into the market will not alter the leader's choice of output. That is, the entrant regards the incumbent as irrevocably committed to its output choice. A further crucial assumption is that the entrant's average cost declines over at least the initial range of low levels of production. When both of these assumptions hold, then by the correct choice of its pre-entry output level, the incumbent can manipulate the entrant's profit calculation and discourage entry.

In Figure 12.1, the appropriate production level to which the incumbent must commit to deter entry is $\overline{Q}$. If the entrant stays out, this implies a market price $\overline{P}$. What would happen to market price if the entrant now produced any positive output? The answer is also shown in Figure 12.1. Because the entrant believes that the incumbent will maintain $\overline{Q}$, the demand the new entrant faces at any price P is the total quantity that is demanded at that price, $D(P)$, less $\overline{Q}$. That is, the entrant faces a *residual demand curve* R^e that, in this case, is simply the market demand curve $D(P)$ shifted inward along the horizontal axis by the amount $\overline{Q}$. Corresponding to this residual demand curve is the entrant's marginal revenue curve MR^e. The entrant maximizes its profit by selecting output q^e at which its marginal revenue just

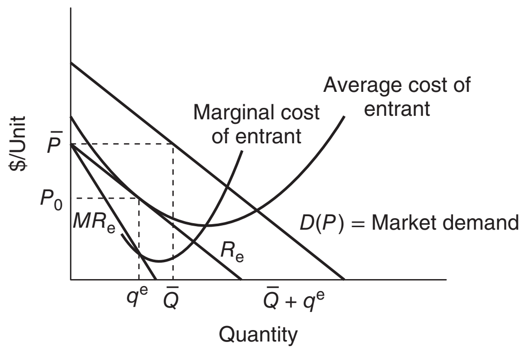

Figure 12.1 The limit output model
By producing at $\overline{Q}$, the incumbent can preclude profitable entry.

equals its marginal cost. As shown in Figure 12.1, this output is such that when it is added to the output $\overline{Q}$ of the incumbent firm market price becomes P_0 and this price barely covers the entrant's average cost. In other words, by committing to the output $\overline{Q}$, the incumbent firm removes any profit incentive for the entrant to actually participate in the market.

12.1 **Practice Problem**

Suppose that market demand is described by $P = 100 - (Q + q)$, where P is the market price, Q is the output of the incumbent firm, and q is the output of a potential entrant to the market. The incumbent firm's total cost function is $TC(Q) = 40Q$, whereas the cost function of the entrant is $C(q) = 100 + 40q$, where 100 is a sunk cost incurred to enter the market.

a. If the entrant observes the incumbent producing Q_0 units of output and expects this output level to be maintained, write down the equation for the residual demand curve that the entrant firm faces.
b. If the entrant firm maximizes profit given the residual demand curve in (a) what output q^e will the entrant produce? (Your answer should be a function of Q_0.)
c. How much output would the incumbent firm have to produce to just keep the entrant out of the market? That is, solve for the limit output $\overline{Q}$. At what price will the incumbent sell the limit output?

It should be clear that successful predation of the type just described depends crucially on the entrant's belief that the incumbent is truly committed to its action. In the language of the last chapter, the strategy must be subgame perfect. The issue then becomes whether this is possible. Can the incumbent truly commit to produce output $\overline{Q}$ even if the entrant enters the market?

Earlier scholars such as Bain (1956) and Sylos-Labini (1962) did not formally address the credibility issue. Nevertheless, they do appear to have understood that in order deter entry the incumbent firm had to commit or "lock in" to the predatory behavior. They assumed that such commitment was achieved by further supposing that the incumbent's output $\overline{Q}$ was "very" costly to adjust. Hence, the potential entrant was correct to assume that the incumbent's output would remain at $\overline{Q}$ because it was too costly to change. In other words, the presence of adjustment costs once the incumbent is already producing at a particular level acted as a mechanism to commit the incumbent to the output $\overline{Q}$ even in the face of entry.

The idea sounds plausible and may well be true. Unfortunately, as stated, it is a little *ad hoc*. Without a full specification of how such costs are generated and how they fit into a complete analysis of strategic interaction between the two firms, the adjustment cost story amounts to little more than a statement that the incumbent's output is given because it is given. Producing $\overline{Q}$ is truly credible only if $\overline{Q}$ is the incumbent's best response to the entrant coming into the market and choosing an output level to produce. Limit pricing can only work if the incumbent firm can commit to producing the limit output even if entry occurs.

12.2.2 Capacity Expansion as a Credible Entry-Deterring Commitment

In a key article, Spence (1977) recognized that what may make limit pricing a credible deterrent strategy is the incumbent firm's ability to make a prior and irrevocable investment in production capacity, and specifically an investment in the *capacity* to produce the limit output $\overline{Q}$. Spence's work was followed by Dixit (1980) who worked out a precise mechanism by which the incumbent could guarantee that in the post-entry market, it would produce an output equal to its pre-entry capacity [See also Gilbert and Harris (1984) and Gilbert (1989)]. As a result, the potential entrant's belief that this will occur is reasonable, i.e., the strategy is subgame perfect. We present the essentials of Dixit's model below. We warn the reader in advance that this model is hard work. While no one piece of the analysis is difficult, considerable care is required in putting all the pieces together.

The game Dixit posits between the two firms is a dynamic, two-stage one in the spirit of those covered in the previous chapter. In the first stage, the incumbent firm is alone and chooses a capacity level that we will denote as $\overline{K_1}$. This commits the firm to a fixed cost of $r\overline{K_1}$ where r is the cost per unit of capacity. One unit of capacity provides one unit of the input K needed to produce one unit of output. Hence, by investing in capacity $\overline{K_1}$ in the first stage of the game, the incumbent firm has the capability of producing any output less than or equal to $\overline{K_1}$ when the second stage of the game begins. However, the incumbent's capacity can be further increased in stage two of the game. Again, this will cost r per unit. The difference is that this is a marginal decision at that time. One can add just one unit of the input K or many at a cost of r apiece. In contrast, the initial $\overline{K_1}$ units of capacity cannot be reduced. They represent a fixed cost in stage two, for which the firm will pay $r\overline{K_1}$ regardless of what its production level is.

The potential entrant observes the incumbent's capacity choice in stage one. It is only after that observation that the potential entrant makes its entry decision in stage two. If entry does occur then, in the second stage of the game, the two firms play a Cournot game in output. Market demand for the product in stage two is described by $P = A - B(q_1 + q_2)$. It is very important to note that the two firms simultaneously choose both their outputs (q_1, q_2) and their levels of input $K(K_1, K_2)$ in stage two. For the incumbent, this input choice is constrained because its capacity in the second stage cannot be less than the capacity chosen in the first stage, i.e., $K_1 \geq \overline{K_1}$. The incumbent firm can increase its capacity in stage two but not decrease it below the precomitted level.

We will denote any sunk costs incurred by the incumbent other than those associated with its capacity choice $\overline{K_1}$ as F_1. For simplicity, we will further assume that every unit produced requires the input of one unit of labor as well as a unit of input K. If labor can be hired at the wage w, then the incumbent's marginal cost of production in stage two for output if $K_1 \leq \overline{K_1}$ is just w. However, if the incumbent wishes to produce an output greater than q_1 then it must expand capacity by hiring additional units of K, again at the price of r per unit, as well as hire more labor at a cost of w per unit. That is, every unit of output above $\overline{K_1}$ has marginal cost $w + r$. These relationships are reflected in the following description of the incumbent's cost function in stage two of the game:

$$C_1(q_1, \overline{K}_1, w, r) = F_1 + r\overline{K}_1 + wq_1; \quad \text{for } q_1 \leq \overline{K}_1 \text{ Marginal Cost} = w$$
$$C_1(q_1, \overline{K}_1, w, r) = F_1 + r\overline{K}_1 + r(q_1 - \overline{K}_1) + wq_1, \quad \text{for } q_1 > \overline{K}_1 \text{ Marginal Cost} = w + r \tag{12.4}$$

The incumbent's marginal cost is w for output up to $\overline{K_1}$ but $w + r$ for higher levels. Now denote any sunk cost the entrant incurs as result of participating in the market as F_2. The entrant's cost function implies that its marginal cost is always $w + r$ no matter what output it chooses, as shown below:

$$C_2(q_2, w, r) = F_2 + (r + w)q_2 \text{ Marginal Cost} = w + r \tag{12.5}$$

Note that for any output q that fully utilizes its capacity equal to $\overline{K_1}$, the incumbent's total cost will be the same as cost incurred by the entrant to produce that same output, namely, $(w + r)q$. That is, the incumbent's initial capacity investment does not give it an advantage in terms of total cost. Instead, what that investment does achieve is a change in the composition of the incumbent's cost. Up to production level $\overline{K_1}$, that cost now reflects an additional fixed cost of $r\overline{K_1}$, and variable cost of just wq_1. In particular, firm 1's advantage is that up to any output less than or equal to $\overline{K_1}$, its *marginal* cost is just w in stage two whereas the entrant faces a marginal cost of $w + r$ for all output levels. This difference is reflected in Figure 12.2, where we draw the marginal cost curve for both firms. The diagram suggests why investment in capacity can have a commitment value. The incumbent's commitment to produce at least as much as $\overline{K}_1$ is made more believable by the fact that up to that production level, its marginal cost is *relatively* low.

In a sequential game, we begin by working out what happens in the last stage in order to work out the incumbent firm's optimal move in the first stage. To solve for a subgame perfect equilibrium strategy for the incumbent firm, we need to determine how the incumbent's choice of capacity in stage one affects the market outcome when the two firms compete in stage two. So, we start by working out what happens in stage two for any particular level

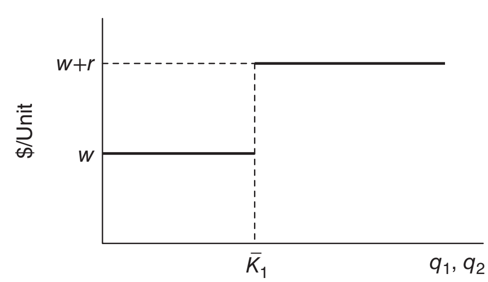

Figure 12.2 The effect of previously acquired capacity on current marginal cost
The incumbent has previously acquired capacity $\overline{K}_1$ and therefore incurs a marginal cost of only w up to this level of production. For greater levels, its marginal cost is $w + r$. The entrant has no previously acquired capacity. Its marginal cost is $w + r$ for all production levels.

of capacity chosen in stage one. We then determine what happens in stage one by choosing the capacity that maximizes the incumbent's profits in stage two.

In stage two, the firms are playing a Cournot game in quantities. From our analysis in Chapter 9, we know that the marginal revenue for each firm is given by:

$$\text{Incumbent Marginal Revenue}: \quad MR_1 = A - 2Bq_1 - Bq_2$$
$$\text{Entrant Marginal Revenue}: \quad MR_2 = A - Bq_1 - 2Bq_2 \tag{12.6}$$

As always, the profit-maximizing output choice for each firm is to produce where marginal revenue equals marginal cost. For the entrant, the implication of this rule is clear. Because the entrant's marginal cost is always $w + r$, its optimal output choice will always be given by the best response function:

$$q_2^* = \frac{(A - w - r)}{2B} - \frac{q_1}{2} \tag{12.7}$$

Recall, however, that the incumbent's marginal cost depends on whether or not the firm is producing beyond its initial capacity investment $\overline{K}_1$. Hence, the incumbent's best response function will also depend on where its production lies relative to $\overline{K}_1$. In particular, we have:

$$q_1^* = \frac{(A - w)}{2B} - \frac{q_2}{2} \quad \text{when } q_1^* \leq \overline{K_1}\text{; and}$$
$$q_1^* = \frac{(A - w - r)}{2B} - \frac{q_2}{2} \quad \text{when } q_1^* > \overline{K_1} \tag{12.8}$$

This means that the incumbent firm's best response function jumps at the output level $q_1^* = \overline{K}_1$. We can see the jump more clearly when we draw the incumbent's best response function in the second stage of the game. We do this in Figure 12.3, where the best response function when marginal cost is just w is shown as $L'L$, while the best response curve when marginal cost is $w + r$ is shown as $N'N$. Again, the incumbent's actual best response curve is a composite of these two line segments that switches from the low-cost curve $L'L$ to the high-cost curve $N'N$ at $\overline{K}_1$, the incumbent's capacity that is given in stage two but chosen in stage one of the game.

One point worth stressing before going further is that the entrant's best response function (12.7) applies on the condition that the entrant chooses to produce any output at all, i.e., so long as $q_2 > 0$. The best response function is derived using the marginal conditions and therefore does *not* take account of the sunk cost F_2 that the potential entrant incurs should it actually decide to enter. The intercept of equation (12.7) with the q_2 axis, namely, $(A - w - r)/2B$ is the entrant's optimal output if the incumbent somehow decided to produce nothing. That would correspond to the entrant being a monopoly and would almost certainly imply positive profits (otherwise we could rule out entry from the start). However, as one moves from left to right along the entrant's best response function, the entrant's output becomes successively smaller as it adjusts to larger and larger output choices by the incumbent. This decline limits the volume over which the entrant's fixed cost F_2 may be spread. As a result, firm 2's average total cost rises as its output falls. It is quite possible that, at some point where the incumbent's output q_1 is sufficiently large, the market price implied by the combined output of both firms will not cover the entrant's average cost *even when it produces the profit-maximizing output implied by its best response curve*. If those

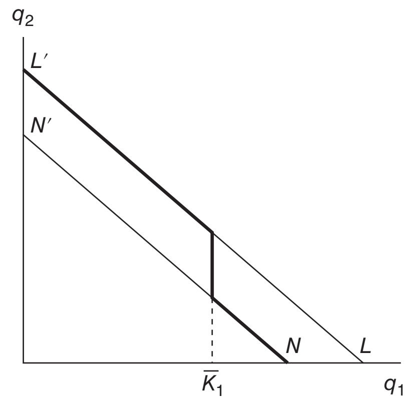

Figure 12.3 The best response function of the incumbent firm depends on its first-stage choice of capacity

For output less than $\overline{K}_1$, the incumbent will have a low marginal cost and operate on the higher response function $L'L$. For output greater than $\overline{K}_1$, the incumbent will have a high marginal cost and operate on the lower best response function $N'N$.

fixed costs had already been incurred they would be sunk and the entrant would continue to produce. Yet because the cost F_2 is only incurred if entry occurs, firm 2 can avoid this expense by choosing not to enter. Obviously, it will do this if it foresees that the Nash equilibrium if it does enter will not generate an operating profit sufficient to cover that cost F_2. We will return to this point below.

Now consider the incumbent's initial capacity choice $\overline{K}_1$. It is clear that this choice will critically affect the Nash equilibrium in stage two. The larger is $\overline{K}_1$, the more likely it is that the state 2 equilibrium will occur along the best response function of the incumbent that is further to the right, i.e., at a point at which the incumbent has a marginal cost of w instead of $w + r$. How should the incumbent make this choice in stage 1?

A little reflection on our analysis in Chapter 11 should convince you that the incumbent's choice for $\overline{K}_1$ will never be less than the Stackelberg leader's choice for output when it has a marginal cost of $w + r$. From that chapter we know that output level is $q_1 = \dfrac{(A - w - r)}{2B}$ and we will now denote this output level as M_1. We also know that if firm 1 does produce this level, firm 2's best response is to set $q_2 = \dfrac{(A - w - r)}{4B}$, an output level we will now denote as M_2. It is actually rather straightforward to understand why the incumbent will never choose an initial capacity less than M_1.

Consider the following. If the incumbent produces at the Stackelberg leader level, the entrant will either stay out of the market entirely or, enter and produce its best response to the Stackelberg output, namely, M_2. The decision to stay out will reflect the fact that if it does enter, the entrant's fixed cost is sufficiently high that it will still lose money even if it produces its best response to the incumbent's Stackelberg output, i.e., when it produces M_2. In other words, if the incumbent's production of M_1 creates enough downward pressure on price that the entrant cannot enter profitably at any output of M_2 or less, then the incumbent will be alone in the market as a monopolist. However, this means that the incumbent will be producing exactly the right amount because we know that the Stackelberg leader output M_1 *is* precisely the output level chosen by a monopolist. Indeed, that is why we designated this output level as M_1. Note that there is no real predation in this case. The incumbent is

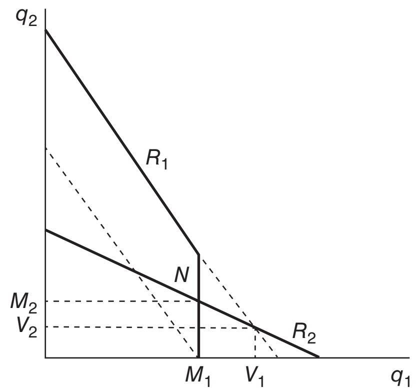

Figure 12.4 Possible incumbent capacity choices and entrant responses
The incumbent will make an initial capacity investment somewhere between points M and V, i.e., in the interval M_1 to V_1. The incumbent will choose the Stackelberg/monopoly capacity of M_1 if: 1) the entrant cannot break even at an output less than M_2; or 2) the entrant can break even at output levels lower than V_2. In the first case, the incumbent is acting as a non-predatory profit-maximizing monopoly. In the second, entry can only be limited—not prevented—by choosing the Stackelberg output. Predatory entry deterrence can occur when the entrant can break even at output levels less than M_2 but greater than V_2 while on its best response curve R_2. Here, the incumbent's investment in initial capacity in excess of M_1 may prevent entry.

simply acting as the monopolist it is by producing the monopoly output and that in itself is enough to block entry and confirm the incumbent's monopoly status.

In the event that entry does occur, the incumbent will face an actual rival in stage 2. Yet if entry cannot be prevented altogether it can still be limited. Moreover, the Stackelberg leader output $M_1 = \dfrac{(A - w - r)}{2B}$ is by definition the best output choice for this purpose. It limits the entrant to $M_2 = \dfrac{(A - w - r)}{4B}$.

Note that for either of the two events above to be subgame perfect outcomes, the incumbent's commitment to producing the Stackelberg output M_1 must be credible. In particular, that output must be a best response to the entrant's choice. Because M_1 is the monopoly output, this is clearly the case if the entrant does not enter. Yet unlike the conventional Cournot model in which the incumbent faces a constant marginal cost of $w + r$ and therefore wishes to reduce its output below M_1 when the rival produces M_2, the *ex ante* investment in capacity also makes M_1 a best response to the entrant's choice of M_2 here. This is shown in Figure 12.4. In this diagram, the sloping dashed lines reflect the incumbent's best response curve under different marginal costs. The inner dashed curve reflects a high marginal cost of $w + r$. The outer dashed line reflects the lower part of the incumbent's best response curve when it has a low marginal cost w. The rest of that best response is reflected in the solid line extension of the outer dashed line. That solid line together with the vertical solid line through output $q_1 = M_1$ together describe the incumbent's best response function, R_1. The entrant's best response function R_2 is less complicated as it reflects the high marginal cost $w + r$ for all output choices.

Note that by investing in capacity $\overline{K}_1 = M_1$ *ex ante*, the incumbent guarantees itself an *ex post* marginal cost of just w up to the output level M_1. This is why we say that R_1 includes the vertical portion through the output level $M_1 = \dfrac{(A - w - r)}{2B}$ implying that this is a best response to a variety of entrant production levels, including the entrant's best response of $M_2 = \frac{(A - w - r)}{4B}$ to the incumbent's choice of M_1. As a result, the incumbent's commitment to M_1 is credible and the output combination $q_1 = \frac{(A - w - r)}{2B}$, $q_2 = \frac{(A - w - r)}{4B}$ is a subgame perfect Nash equilibrium.

We have just shown that the incumbent will never invest in initial capacity $\overline{K}_1 < M_1$. In addition to this lower bound on its initial investment there is also an upper bound. This is the output level shown in Figure 12.4 as V_1, corresponding to the Nash equilibrium when the incumbent has the low marginal cost w throughout its production. The reason should be clear. While it is feasible for the incumbent to set $\overline{K}_1 > V_1$, such higher outputs cannot be part of a Nash equilibrium in a post-entry game. There is no point to the right of V at which the best response function of the incumbent R_1 will intersect the best response function of the entrant R_2. Because the incumbent will never wish to produce more than V_1 it will never wish to invest in $\overline{K}_1 > V_1$ initial capacity.

So far, we have shown that the incumbent will never make a stage one investment in capacity either less than M_1 or greater than V_1, i.e., we must have $M_1 \leq \overline{K}_1 \leq V_1$. The remaining question is whether the incumbent will ever choose an initial capacity $\overline{K}_1$ somewhere in between this upper and lower bound. That is, is it possible to have a subgame perfect equilibrium in which $\overline{K}_1$ exceeds M_1 but is less than V_1? To see why this is possible, consider Figure 12.4 again in which we have assumed an initial capacity choice of exactly $\overline{K}_1 = M_1 = \frac{(A - w - r)}{2B}$. This choice in turn implies that the stage two equilibrium will be at point M (the Stackelberg point) with firm 1 producing at capacity M_1 and firm 2 producing at $M_2 = 0.5M_1$. Suppose though that in this equilibrium the entrant's output M_2 generates just enough operating profit to cover its fixed cost F_2. Hence, in this equilibrium the entrant breaks even, i.e., the market price just covers the entrant's average total cost.

Starting from this point, it is clear from equation (12.7) that if the incumbent increased its output by one unit to $M_1 + 1$, the entrant's output would fall by $1/2$ unit. So, total output would rise by a $1/2$ unit implying that the market price would fall. Yet because it would now be spreading its fixed overhead cost F_2 over a smaller volume, the entrant's average cost will have risen. It follows that if it had just been breaking even in the previous market outcome, the entrant will now be losing money because the price per unit has fallen and the cost per unit has risen. Foreseeing this, however, the entrant would not enter in the first place. It is better not to enter and earn zero rather than to enter and actually lose money. In other words, this is a situation in which, by committing to an output of $M_1 + 1$, the incumbent can deter the entrant from entering the market at all. To be sure, the output $M_1 + 1$ is a little higher than the profit-maximizing monopoly output of $M_1 = \frac{(A - w - r)}{2B}$. However, as we have seen, the commitment to a higher output level is what makes monopoly possible in the first place. The lower output choice of M_1 allows the entrant in to compete as a Stackelberg follower. In the case at hand, that rivalry will reduce the incumbent's profit more than the cost of choosing slightly more capacity than it would have had it been a monopoly not facing entry. In other words, the incumbent's choice comes down to this: commit to producing $M_1 = \frac{(A - w - r)}{2B}$ units which will permit the entrant to enter and produce $M_2 = \frac{(A - w - r)}{4B}$ units so that the incumbent earns the profit of a Stackelberg leader, or commit to $M_1 + 1$ units which will prevent the entrant from coming into the market at all and leave the incumbent with the monopoly profit from producing $M_1 + 1$ units, which is a little less than a pure monopolist facing no entry. It should be clear that the latter choice will often be preferable. Indeed, even if it has to increase its initial capacity investment to $M_1 + 2$, or $M_1 + n$ in order to deter entry, the incumbent may find it profitable to do so, so long as n is not so large that the incumbent commits to a level of output greater than V_1.

In sum, there are three possibilities in the Dixit (1980) model. One is that the entrant's fixed cost F_2 is sufficiently high that it cannot operate profitably at any point along its best response curve that has an output less than or equal to that of a Stackelberg follower ($\leq M_2$ in Figure 12.4). A second possible outcome is that the entrant's fixed cost F_2 is sufficiently low that it can profitably enter even in a Nash equilibrium (point V in Figure 12.4), in which the incumbent's marginal cost is just w reflecting only its labor input, so that the entrant's output is very low (V_2 or lower in Figure 12.4). In either of these cases, the incumbent will find it optimal to commit to a capacity level of $\overline{K}_1 = M_1 = \frac{(A - w - r)}{2B}$. If the entrant cannot enter, this is the right value because it is the output that a monopolist would choose. If the entrant cannot be blocked, this is the output level that best limits the extent of entry. However, there is a range of entrant fixed cost F_2 not so large that the incumbent's commitment to a capacity level $\overline{K}_1 > M_1 = \frac{(A - w - r)}{2B}$ will deter entry but large enough such that commitment to capacity $\overline{K_1}$ satisfying $V_1 \geq \overline{K_1} > M_1$ will imply losses for the entrant even if it makes its best response to the incumbent's choice because it will not achieve sufficient scale economies. In this case, predatory entry deterrence *is* possible. We say predatory because the incumbent would not normally choose an initial capacity of $\overline{K}_1 > M_1$ except for the fact that this deters all entry, i.e., the action is profitable only because of its entry deterring effect. This is the common definition of market predatory behavior. Practice Problem 12.2 provides a numerical example of this analysis. Formal analysis of the Dixit (1980) model may be found in the Appendix to this chapter.

Practice Problem 12.2

Suppose that the inverse demand function is described by $P = 120 - (q_1 + q_2)$, where q_1 is the output of the incumbent firm and q_2 is the output of the entrant. Let both the labor cost and capital cost per unit be 30, i.e., $w = r = 30$. In addition, let each firm have a fixed cost of $F_1 = F_2 = 200$. (See Figure 12.5 for illustration.)

a. Suppose that in stage one the incumbent invests in capacity $\overline{K}_1$. Show that in stage two the incumbent's best response function is $q_1 = 45 - \frac{1}{2}q_2$ when $q_1 \leq \overline{K}_1$, and $q_1 = 30 - \frac{1}{2}q_2$ when $q_1 > \overline{K}_1$.

b. Show that the entrant's best response function in stage two is $q_2 = 30 - \frac{1}{2}q_1$.

c. Show that the monopoly or Stackelberg leader's output is equal to 30. If the incumbent commits to a production capacity of $\overline{K}_1 = 30$ show that in stage two the entrant will come in and produce an output equal to 15. Show that in this case firm 2, the entrant, earns a profit equal to \$25, whereas the incumbent earns a profit of \$250.

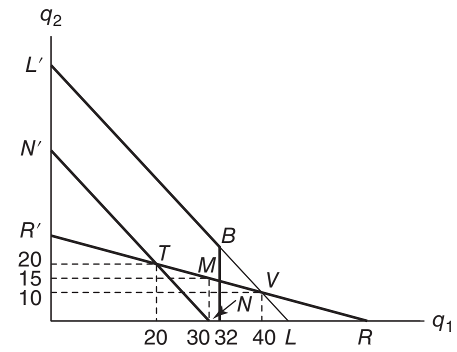

Figure 12.5 An example of entry deterrence
By initially investing in capacity of 32 in stage one, the incumbent firm insures that it will operate on the response function $L'L$ up to this output level in stage two. It also signals the potential entrant that the incumbent will produce an output of $q_1 \geq 32$ in this later stage. The entrant's best response to this production level is to set $q_2 = 14$. However, the entrant will not cover its cost even with this best response. Therefore, by committing to an output of $q_1 = 32$, the incumbent deters any actual entry.

d. Now show that if the incumbent chooses a $\overline{K}_1 = 32$ in stage one then the entrant in stage two can not earn a positive profit if it enters the market. In this case, the incumbent produces slightly more output than the monopolist and earns a profit equal to \$632, which is far greater than the profit earned in part (c).

The Dixit (1980) model makes clear that the incumbent firm has an advantage. More importantly, the model reveals precisely the source of that advantage. It is the incumbent's ability to commit credibly to a particular output level in stage two by means of its choice of capacity in stage one. Effectively, the incumbent commits to producing at least as much as the initial capacity it installs because to produce any less amounts to throwing away some of that investment, which is costly. In this respect, two further aspects of the model are worth noting. First, when the incumbent deters entry it does so by deliberately *over*-investing in initial capacity. That is, installing an initial capacity greater than M_1 would not be profitable were it not for the fact that doing so eliminates the competition. Therefore, such capacity expansion is predatory in the usual sense of the word.

Second, note that capacity expansion is credible as a deterrent strategy only to the extent that capacity, once in place, is a sunk cost. If unused plant capacity can be sold off for a fee r, then capacity is truly flexible and acquiring it does not reflect any real commitment on the part of the firm. When such flexibility is not possible, which is often the case, then capacity investment is a much more effective way to deter strategy than simply a promise to set a low price. A price commitment is much less credible precisely because it may easily be changed. Making a real commitment is typically costly. In the Dixit model, this cost reflects the fact that the incumbent operates at a level of output above the profit-maximizing choice of a pure monopoly. Yet it is precisely the act of making that commitment and incurring that cost that makes monopoly possible. Practice Problem 12.3 offers another model of predation by way of commitment.

Now think back to the empirical evidence on entry that we reviewed at the beginning of the chapter. Two of the stylized facts are: (1) entry is commonly observed in a wide

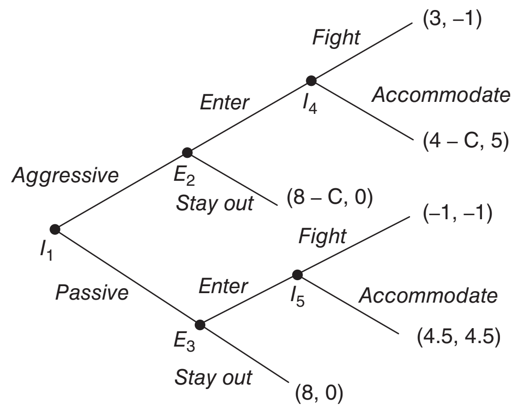

Figure 12.6 Extensive form for practice problem 12.3
At nodes labeled I it is the incumbent's turn to move. At nodes labeled E it is the entrant's turn.

cross-section of industries, and (2) market penetration as measured by market share is relatively low for the entrants. These stylized facts are consistent with this model. The incumbent has a strategic advantage in being the first to invest in capacity, and can use this advantage strategically to limit the impact of entry into its market—perhaps eliminating it altogether.

12.3

Practice Problem

The extensive form for a dynamic game between an incumbent and an entrant firm is described in Figure 12.6. The incumbent firm moves first and chooses whether or not to spend C as a means of enhancing its ability to be aggressive. The entrant moves next and decides whether or not to enter the market. If the entrant enters then the incumbent decides whether to accommodate its new rival or to fight. If the entrant does not enter, the incumbent earns 8 minus C if it has made that expenditure, and 8 if it has not. If the entrant does enter, the incumbent's payoffs depend on whether it fights or accommodates. Fighting when the expenditure C has been sunk yields a payoff of 3. Fighting is bloodier when the incumbent has not spent C. Accommodation when C has been spent wastes that investment. The final payoffs are described in parentheses, the first being the incumbent's payoff and the second the entrant's.

a. Show that for C greater than or equal to 1, the incumbent will always fight *if* it has invested in the capacity to do so—that is, if it has initially made the expenditure C.
b. Show that for C greater than or equal to 3.5, the incumbent will not make the initial investment C.

12.3 PREEMPTION AND BUNDLING

A central force that drives the Dixit (1980) model is the presence of scale economies. The fixed cost F_2 of the entrant must be spread over a sufficiently large volume of output in order for its average cost to be sufficiently low. This is often the case because the scale of a

Reality Checkpoint

Take-or-Pay ... and Win!

Firms typically have contracts with their key suppliers that stipulate the amount of the input to be bought and the price to be paid for the coming year. A common additional feature of such contracts, especially for supplies of natural gas, electricity, and commodity raw materials, is a "take-or-pay" clause. A contract that includes a take-or-pay clause requires that the purchasing firm either uses all the amount of the input initially contracted or, that if it orders less than that amount, it still pays some amount, usually less than the full contract price, for the additional amount remaining.

Take-or-pay contracts stabilize both the production schedule and the revenues of supplier firms. However, as you should recognize, they also serve another purpose. They are a straightforward way to implement the Dixit entry deterrence strategy.

For example, Corning is one of the leading manufacturers of fiber optic cables. One of its key suppliers is Praxair, a major producer of specialty gases. Suppose that Corning signs a contract with Praxair that calls for Corning to purchase 1,000,000 cubic feet of helium (which is used as a coolant in the production of fiber optic cable) at \$400 per 1,000 cubic feet. The contract also includes a take-or-pay contract where Corning has to pay \$300 per cubic feet for any amount of the 1,000,000 that it does not use. What this does is effectively transform the structure of Corning's costs. If Corning orders all of the 1,000,000 cubic feet, its helium bill will be: $(\$400/1000) \times 1{,}000{,}000 = \$400{,}000$. Suppose though that Corning only uses 900,000 cubic feet of helium (perhaps because a new rival steals some Corning customers). Because of the take or pay clause, it will still pay \$300 per thousand cubic feet for the 100,000 cubic feet that it did not order. Hence, Corning's total helium cost in this case will be: $(\$400/1000) \times 900{,}000 + (\$300/1000) \times 100{,}000 = \$390{,}000$. In other words, using the last 100,000 cubic feet of helium only raises Corning's total helium bill by \$10,000. Effectively, the contract has changed the marginal cost of helium for Corning from \$400 to \$100 per thousand cubic feet. Note that it has not changed the total cost of using one million cubic feet of helium. The contract has simply transformed some of those costs into fixed costs so that up to the one million volume, Corning has a very low marginal cost.

There is of course a downside to the take-or-pay contract. This is that if another large rival, e.g., the British fiber optic producer Marconi, already exists and both firms sign take-or-pay contracts with their helium suppliers, the industry could find itself in a nasty price war in which prices fall to the low levels of marginal cost via Bertrand competition. Some believe that this is part of what happened in the fiber optic market following the burst of the telecommunications bubble.

Sources: A. M. Brandenburger and B. J. Nalebuff, 1996. *Co-opetition*. New York: Doubleday; and F. Norris, "Disaster at Corning: At Least the Balance Sheet is Strong," *New York Times*, July 13 2001, p. C2.

plant or plant capacity is frequently not a continuous but a discrete variable—available only in specific, fixed amounts. This same scale economy feature also plays a role in other entry deterring strategies but ones that while similar, are logically distinct from the mechanism of the Dixit (1980) model. Two of these strategies include an investment timing tactic generally referred to as preemption and the strategic use of bundling. We discuss each in turn.

12.3.1 Preemption

While the intuition underlying the preemption analysis has long been understood, the first formal analysis is due to Eaton and Lipsey (1979), and is set in a spatial market framework of the type introduced in Chapters 4, 7, and 10. We illustrate the basic idea here using a simple numerical Cournot example.

Consider a monopolist facing current demand given by: $Q = 30 - P$, so that inverse demand is $P = 30 - Q$. Operating in this market requires a plant, and these come only in one size. Specifically, each plant can product any output up to a capacity of 15 units. Such a plant can be built and utilized instantaneously and it will last forever, but acquiring a plant of this capacity requires a one-time cost of \$150. For simplicity, we assume all other costs are zero. Hence, once the plant is built, the firm has a marginal cost of zero. By either the twice-as-steep rule (Chapter 2) or the Cournot $N/(N+1)$ rule (Chapter 9) with $N = 1$, it should be easy to see that the monopolist's profit maximizing output is $Q^M = 15$, implying a monopoly price of $P^M = \$15$ and an operating profit of \$225, or a net monopoly profit of $\pi_1^M = \$75$, after the cost of building the necessary plant is included.

We now complicate this setting with two additional features. The first of these is that there is a potential entrant against whom the monopolist will compete as a Cournot duopolist should entry actually occur. The second is that there is a subsequent market period in which demand will grow to: $Q = 42 - P$, i.e., it is known that the market will increase by 40 percent over time. If this seems like very rapid growth, think of a period as say ten years so that it reflects an annual growth rate of 3.4 percent. Of course, this time element implies that discounting is relevant. We will assume a periodic interest rate of 50 percent (4.1 percent a year if a period is ten years). This implies that the discount factor $R = 0.67$.

In the absence of the entry threat the incumbent would reason as follows. If it does not add capacity by building another plant, it will sell 15 units in period two. Given the increased demand, these units will sell at a price of \$27 each and the firm will earn a profit of \$405. Given the discount factor, the present value of this profit is $R\$405 = \$270$. Alternatively, the firm can acquire a second plant for \$150 either now or in the second period. From a present value perspective, the latter option is clearly better as the present value of the cost is then just $R\$150 = \$100$. If it has a capacity of 30 units, then again, use of the $\left(\frac{N}{N+1}\right)$ rule (Section 9.5) implies that with $N = 1$, the monopoly output in period two is 21 units implying a price of \$21, and a revenue of \$441. In present value terms, this has value of $R\$441 = \$294$. Thus, the present value of adding a second plant to expand capacity is $\$294 - \$100 = \$194$. Because this is less than the present value (\$405) of simply producing at the current capacity of 15, the incumbent would not add any capacity in the absence of any entry threat.

We now turn to the potential entrant. This firm observes the incumbent in period one and decides then whether or not to enter in period two. To do so obviously requires that this firm make the \$150 investment in a plant. However, it has a choice about when it should do this. It can invest in the plant now and pay a present value of \$150 or wait one period and pay a present value of $R\$150 = \$100$. As a Cournot duopolist in the second period, the $N/(N+1)$ rule implies that both the entrant and the incumbent will produce 14 units in period two. This will lead to a second period price of \$14. Therefore, the present value of the operating profit each firm will make is $R\$196 = \$130.67$. Clearly, this is not enough to cover the cost of investing in a plant today but is enough to cover the cost if investment is delayed one period. Accordingly, the entrant will wait until the second period to acquire the necessary plant to enter the market.

We now return to the incumbent. It understands the logic of the above analysis and can see that the entrant will enter invest and enter in period two, which will end its monopoly position. Is there a strategy that the incumbent can use to prevent this?

Here we make one further assumption. This is that while the two firms compete as symmetric Cournot duopolists if they invest at the same time, each with a marginal cost of zero, this is not the case if one firm builds capacity before the other. More specifically, if one firm adds capacity before the other, it gains all the consumers it can serve up to its new capacity. Only if demand is more than that expanded maximum will its rival gain any customers. This may be because by being first, the firm can sign up consumers to a contract before its rival, or for other reasons. In a spatial model setting, it reflects the fact that once a firm has staked out a market position it cannot move. Whatever the reason, however, it now gives the incumbent an incentive to invest in period one—to preempt the entrant's later expansion—and so to keep its monopoly position.

The logic of the incumbent's new strategy is straightforward. There is clearly no point in investing in new capacity in period two because the entrant will still find it profitable to enter at that time. Thus, the incumbent's choice comes down to either not investing at all as per its original strategy or expanding capacity in period one. In the former case, the entrant will enter and the incumbent will earn a second period duopoly operating profit of \$196. The present value of its profit over time will then be: $-\$150 + \$225 + R\$196 = \$205.66$. Alternatively, the incumbent can expand capacity now by initially building two plants giving it a capacity of 30—more than enough to serve all the output demanded at the duopoly price of \$14. As a result, the entrant will see that entry is not profitable and the incumbent will keep its monopoly position. Now, with a capacity of 30 in period two, the incumbent will produce the profit-maximizing output of 21 units, implying a price of \$21 and an operating profit of \$441. The present value of its cash flow in this case is: $-\$300 + \$225 + R\$441 = \$219$. It is evident then that investing in additional capacity today is the more profitable strategy. Therefore, the incumbent will add an additional plant in period one as a means to preempt the entrant and maintain its monopoly power.

The reason that the incumbent can afford to expand capacity in period one while the entrant cannot is straightforward. The incumbent is fighting to protect monopoly profit while the best that the entrant can hope for is a duopoly profit. Thus, the payoff to early capacity expansion is greater for the incumbent than it is for the entrant.

Note two further features of the preemptive capacity expansion just described. First, the strategy implies that in period one the incumbent will operate with a lot of excess capacity. Specifically, it will have a capacity of 30 units and yet produce only half that amount. Second, and even more important, note that the incumbent's first-period capacity expansion would not be profitable—and the incumbent would not do it—except for the fact that the investment works to prevent entry. Viewed in this light, this preemptive strategy is truly predatory.

12.3.2 Bundling to Deter Entry

In Chapter 8, we presented the use of bundling as both a price discrimination technique and as a predatory tactic with particular reference to the Microsoft case. The underlying analysis of this second role, due to Nalebuff (2004) among others, is worth reviewing briefly here with a simple numerical example. To this end, consider the following valuation of two different goods, A and B, by each of ten potential buyers.

Consumer	*Value of Product A*	*Value of Product B*	*Value of Both Products*
1	0.5	5.0	5.5
2	1.0	8.0	9.0
3	1.5	6.0	7.5
4	2.0	3.0	5.0
5	2.5	3.9	6.4
6	3.0	4.0	7.0
7	3.4	3.9	7.3
8	4.0	6.0	10.0
9	4.5	8.0	12.5
10	5.0	10.0	15.0

The current incumbent has a marginal cost of \$1 per unit of each good. Each consumer will buy at most one unit of either commodity, depending on whether the price exceeds or is less than the consumer's valuation. As a little experimentation will quickly reveal, the profit-maximizing values for the two prices P_A and P_B if they are sold separately are $P_A = \$3$ and $P_B = \$3.9$. At these prices, five consumers will buy product A and nine will buy product B. As a result, the incumbent will earn an operating profit of \$10 in market A and \$26.1 in market B for a total profit of \$36.1. If instead the firm bundles the two products as one packaged combination, the profit-maximizing bundle price is \$6.4 at which price eight consumers will buy the package. Because the production cost of the bundle is \$2, this strategy will lead to an operating profit of $8 \times (\$6.4 - \$2) = \$35.2$. Because this is less than \$36.1, this is a case in which the incumbent would not engage in pure bundling.

However, the potential entry of a rival might change matters. Suppose that a more efficient rival for the A market emerges. This rival offers a perfect substitute for the incumbent's product A and does so at a lower cost. Specifically, the rival has the same fixed cost of \$5 but a marginal cost of zero. Clearly, if this firm enters, it can set a price P_A of (just under) \$1, and steal all of the incumbent's market A customers. The incumbent will still earn an operating profit of \$26.1 from its B product line but nothing from its A product line. Meanwhile, by selling nine units of A at a price of \$1, the entrant would earn \$9 in revenue, which is more than enough to cover its variable cost (\$0) and its fixed cost (\$5).

Bundling may offer a means of preventing this entry. As noted in Chapter 8, bundling allows the firm to attract those potential A consumers who also place a large value on product B. If it can attract enough of these, it can make it impossible for the entrant to cover its fixed overhead cost. For example, suppose that the incumbent offers goods A and B together as a bundle for a bundle price of \$6, while the entrant continues to offer good A at price $P_A = \$1$. Each consumer now has the choice of buying either just product A from the entrant at a price of \$1 or products A and B together in a bundle offered by the incumbent at a price of \$6. Because consumers maximize the surplus they get from any purchase, consumer 1 will buy neither alternative, while consumers 4 through 7 buy product A alone. The resultant revenue of \$4, however, is not enough to cover the entrant's fixed cost and so entry would not occur (if it did it would soon be followed by exit). This leaves the incumbent selling the bundle for \$6 which, in the absence of any rival goods, will now sell to eight consumers implying a net profit of $8(\$6 - \$2) = \$32$. Because this profit is more than the incumbent earns if it accepts the rival's entry and simply sets the profit-maximizing price of \$3.9 in the *B* market, the incumbent will now find it profitable to bundle.

It is important to remember that the incumbent's decision to bundle in the foregoing example is only profitable because it keeps out new entrants. In the initial market setup with no threat of entry the incumbent did not find bundling profitable. It is the ability of bundling to prevent entry (or drive out existing rivals) that makes it a profitable strategy. Again, this is what economists mean when they talk about predatory behavior.

12.4 PREDATORY ENTRY DETERRENCE: HISTORICAL CASES

Both the Dixit-Spence and the preemption models discussed in the preceding sections suggest that dominant firms may expand capacity rapidly as a means to deter entry. In one case, this reflects a change in the cost structure that allows the firm to commit to aggressive pricing if entry does occur. In the other case, it serves as a preemptive claim on future customers. Is there any evidence that such capacity expansion motivated by rival entry actually occurs?

The answer to this question is, "It depends." It would be inaccurate to say that the available evidence supports the view that incumbents generally engage in such behavior. For example, Lieberman (1987) examines the capital investment behavior of incumbent and entrant firms in thirty-eight chemical industries in the face of excess capacity and market growth. He finds no difference in the behavior of the two types of firms. This suggests that the incumbents are not engaging in any capital investment for the purpose of discouraging entry. Moreover, because investment commitment strategies are more likely to occur in more capital-intensive industries, one might expect profitability to be higher in such industries, all else equal, if preemptive expansion is the norm. However, an early study by Caves and Ghemawat (1986) does not find support for this result.

Yet there is a difference between finding no evidence that capacity expansion motivated by entry deterrence is an empirical regularity and finding no evidence that such behavior ever occurs at all. To begin with, different conditions across markets have different implications for what entry deterring behavior is to be expected. For example, while the models described above have been set in a duopoly context, the reality is that there is often more than one such potential rival. One possibility in this case is a free rider problem in which successful entry by one firm will lead to many more entrants that erode that first entrant's profitability. In such a setting, it may take very little capacity expansion on the part of the incumbent to deter any entry. So, the fact that we do not see such much excess capital investment in such markets does not necessarily mean that entry deterrence is not taking place if there are many potential entrants. A second free rider problem arises if there is more than one incumbent. If one firm's capacity expansion is enough to deter entry, each incumbent may decide to let its current rivals take on that cost with the result that the observed excess investment in entry-deterring capacity is again small.[9]

The difficulties in formally testing a generalized model of entry deterrence via capacity expansion suggest that we must instead rely on the alternative approach of looking for such behavior in specific, well-defined markets. This is the approach we take here. In the following section, we present formal analysis based on evidence from hotel chains operating in Texas.

9 See Gilbert and Vives (1986) for a contrary view in which capacity expansion grows as concentration falls in a Cournot setting.

Perhaps the clearest case of capacity expansion to deter entry is provided by the Alcoa case of 1945 [*U.S. v. Aluminum Co. of America*, 148 F. 2d 416 (1945)]. As the court noted in finding Alcoa guilty of illegal monopolization, the dominant aluminum refiner expanded capacity eight-fold between 1912 and 1934. The court felt that this prevented all but two attempts to enter the industry both of which failed for lack of sufficient market share.

Weiman and Levin (1994) find that preemptive investment was an explicit tactic of Southern Bell Telephone (SBT) in its effort to monopolize the local phone service market in the central southern and eastern southern regions of the United States. Those markets had become intensely competitive after the expiration of the Bell patents so that by 1902, independent firms accounted for 60 percent of the local phone service in the region from Virginia to Alabama and Florida. Weiman and Levin (1994) provide a detailed review of company archival records showing that SBT's leader, Edward J. Hall, launched an aggressive capital expansion program to build a regional toll network in anticipation of market development and with the explicit goal of preempting rivals. Within four years, SBT had increased the geographic reach of its system from 2,000 to 8,600 pole miles. Even more impressively, its calling capacity as measured by toll wire coverage grew from 5,000 to over 55,000 miles. All this was accompanied by an aggressive price-cutting campaign both in markets where it faced competition and those where it expected it. Among other features, this had the effect of restricting the investment funds available to competitors for their own expansion whereas SBT was able to rely on heavy financing from its parent firm, AT&T. The plan worked. By 1912, SBT had virtually complete control of the southern local telephone market.

A third example is set in the town of Edmonton, Alberta, during the 1960s and early 1970s. The major retail grocer in Edmonton at that time was Safeway. However, in the early 1960s other grocery chains began to enter the Edmonton market. These included two Ontario firms, Loblaws and Dominion, and one Western Canada firm, Tom Boy. Between 1960 and 1963, these three firms opened twelve new stores in the Edmonton area. By 1964, they were operating a total of twenty-one stores—not far behind Safeway's then total of twenty-five. Safeway could clearly see that continued entry by these and other firms was a real possibility and it rapidly responded. It opened four new stores in 1963–64, another four new stores in 1965–66, and then added five new stores in 1968. Moreover, Safeway chose the locations of these new stores quite carefully. It located them in areas where due to increasing population and the fact that no other store was currently close by, it looked like a site of potential entry. In addition, just to drive home the seriousness of its intentions, Safeway also located some of its new stores almost right next to locations where its rivals also had a store. The strategy worked. By 1973, Safeway was operating thirty-five stores in the Edmonton area whereas, due to closings, its three major rivals were operating just ten.[10]

Our final case comes from the market for titanium dioxide. This is a chemical additive used as a whitener in such products as paint, paper, and plastics. At the time of our story, it could be produced by any of three processes. One of these is a sulfate procedure that uses ilmenite ore. One is a chloride process that uses rutile ore. Both of these processes were known and available to all producers. The third process, however, is a special chloride process that because of legal restrictions was known and available for use only by DuPont. Like the sulfate process, DuPont's procedure uses ilmenite ore. Yet like the generic chloride

[10] Safeway was charged with monopolizing the Edmonton market in 1972 and, in late 1973, signed a consent decree that, among other things, prohibited it from expanding its total square footage in Edmonton for three-and-a-half-years. See von Hohenbalken and West (1986).

process, DuPont's method emits little pollution. This is not the case with the sulfate procedure, which has bad pollution affects.

Seven domestic firms were active in the titanium dioxide market during the 1970s. DuPont was the largest of these with about 34 percent of the market, but NL industries—which used the sulfate procedure—was a close second. Then, two events happened in the early 1970s that gave DuPont a decided advantage. First, rutile ore became more expensive, implying that other producers using the generic chloride technique might have to cut back. Second, strict pollution controls were imposed that made the sulfate process very expensive. Suddenly, DuPont's proprietary chloride technique based on ilmenite ore gave the company an edge with respect to costs. A strategic firm would lose no time in exploiting that edge. It would know that those producers using sulfate were not likely to expand. It might also recognize that rutile could someday become cheap again (it did). If in addition the firm expected, as did all participants in the titanium oxide market, that demand would grow, a firm in DuPont's position might wish to expand capacity immediately. This would preclude those rivals using the rutile-based technique from expanding production when and if rutile prices dropped and thus, permit the firm to capture the gap caused by market growth and the declining sulfate-based production entirely for itself.

In fact, DuPont increased its capacity by over 60 percent in the next five years while the industry in general stagnated. By 1977, DuPont's market share had risen to 46 percent. Moreover, when rival Kerr-McGee began to construct a new plant in 1974, just before DuPont got its planned expansion going, DuPont began trumpeting its plans to the whole industry. This seemed deliberately aimed at curtailing any expansion rival beyond that of Kerr-McGee's.[11]

In short, there appear to be a number of individual cases that support the use of capacity expansion to deter entry. Recall moreover that the role of capacity expansion in the Dixit model is to change the structure of a firm's costs as opposed to its total costs. There may be contractual and other ways to achieve this same result (see Reality Checkpoint, "Take or Pay"). Thus, one cannot easily rule out the possibility that firms engage in some such efforts.

We will turn to an explicit econometric analysis of capacity expansion in the next section. Before doing so, however, we ask whether there is also evidence on the use of bundling as an entry deterrent. Here again, the answer is again individualized to specific cases. Clearly, the issue of a large firm using bundling to damage a rival was at the heart of the Microsoft case of 2000.[12] The critical argument there was that by bundling its own web browser, *Internet Explorer*, into its general *Windows* operating system at essentially a zero price, Microsoft made it nearly impossible for the *Netscape Navigator* browser to survive. The issue also arose in connection with Microsoft's *Media Player*, which the European Commission also found harmful to competition.[13]

It is useful in this regard to note that bundling (and tying) can work in rather sophisticated ways. For example, Goolsbee and Syverson (2008) document that airlines flying routes on which the probability that discount airline Southwest has a high probability of entering cut

[11] See Ghemawat (1984). See also Hall (1990) for evidence that DuPont's action was consistent with the Dixit model.

[12] The judge's decision in *United States v. Microsoft Corp*. 97 F. Supp. 2d 59 (D.D.C. 2000) was explicit in its findings of an illegal tying violation of the Sherman Act.

[13] In its ruling in 2004, the European Commission found Microsoft guilty of illegal tying and fined the company €497 million ($613 million). It also ordered Microsoft to share technical documents with rivals and market a version of Windows without *Media Player*. See *Microsoft Corp. v. Commission of the European Communities, T-201/04*, March 24, 2004.

prices dramatically in advance of any actual entry. Given airline frequent flyer programs this not only expands the incumbents' market demand immediately but also in the future. In effect, frequent flyer programs may be thought of as the bundling of two goods differentiated by time, namely, air travel today and air travel in the future. By locking in future air passengers, this tactic may again make Southwest's actual entry more difficult.

12.5 EMPIRICAL APPLICATION: EXCESS CAPACITY EXPANSION IN TEXAS HOTELS

Because the use of entry-deterring tactics reflects strategic consideration, we will not observe its use by perfectly competitive firms. Moreover, entry deterrence efforts may be limited even in less than perfectly competitive markets, given that each incumbent is tempted to free ride on the entry deterring actions of others. Only when an incumbent has a large market share will it find it worthwhile to engage in entry-deterring behavior. The overall intuition then is that entry-deterring tactics ought to be more commonly employed in more concentrated markets[14] and by larger firms.

Conlin and Kadiyali (2006) apply the foregoing insight to hotel markets across 254 counties in Texas over the years 1991 through 1997. Following the intuition of the Dixit (1980) and Eaton and Lipsey (1979) models above, they identify entry deterrence with excess capacity.[15] Their basic hypothesis is therefore that there will be more excess capacity—a higher percentage of unoccupied rooms—in more concentrated markets and for firms with larger market shares.

Conlin and Kadiyali (2006) apply four different definitions of the local hotel market. One is simply the county: all hotels in Anderson county form one hotel market. A second is the more local city market: all hotels in Houston form one market. Variations on each of these two basic definitions come from considering which of three specific hotel segments—Full Service, Limited Service, or Extended Stay—forms the core of the hotel's business. Again, examples would include the Anderson County Full Service hotel market and the Houston Limited Service hotel market. With these data, Conlin and Kadiyali (2006) create a Herfindahl Index for each such market. They also measure the percentage excess capacity in each market in each year, defined as $100\% \times (1 - \textit{the average occupancy rate})$. They then estimate the following regression for each market group across all the sample years:

$$\text{Percentage Excess Capacity}_{m,t} = \alpha_t + \beta(\text{Herfindahl Index})_{m,t} + \varphi X_{m,t} + \varepsilon_{m,t} \tag{12.9}$$

The dependent variable is the percentage excess capacity in market m and year t. The intercept varies over time to allow for the general economic conditions of each year. The expectation is that the Herfindahl Index for market m in year t will have a positive effect on market excess capacity, i.e., β will be positive reflecting the hypothesis that more concentrated markets will exhibit more entry-deterring behavior. However, the authors control for a variety of other influences on excess capacity such as unemployment, per capita income, population, taxes, etc., by including the vector of variables $X_{m,t.}$ Of course, there is also a random error term $\varepsilon_{m,t}$ associated with each regression observation. The

[14] See Gilbert and Vives (1986) for an alternative view in which entry-deterring capacity expansion falls with concentration.

[15] Bulow et al. (1985) show that the incumbent in the Dixit model will have excess capacity when demand is nonlinear.

Table 12.2 Effect of market concentration on excess capacity in local texas hotel markets

Market Definition	*Herfindahl Index Estimated Coefficient*	*Standard Error*
County	0.478*	(0.167)
County-Sector	0.159	(0.154)
City	0.345*	(0.129)
City-Sector	0.240**	(0.129)

*Significant at 1% level;
**Significant at 10% level

estimates of the key parameter β for each of the four different market definition regressions are shown above in Table 12.2.

The results tend to confirm the hypothesis that increased concentration is associated with increased excess capacity in Texas hotel markets. All four of the estimated concentration coefficients are positive and three are statistically significant. Thus, these results offer support for the view that firms with market power pursue capacity expansion as an entry deterrent.

Yet while supportive of the basic hypothesis, Conlin and Kadiyali (2006) recognize that these findings are far from conclusive. The reason is that while, as noted, they have controlled for many other observable differences between markets, such as unemployment, population, and so on, there may be other, unobservable differences that are driving these results. For example, the presence of excess capacity may cause hotels to exit a local market. Moreover, it may be the smallest hotels that leave first. As these small hotels exit, market concentration increases giving rise to a positive correlation between excess capacity and concentration that does not at all reflect an entry-deterring strategy. Similarly, it may be that highly concentrated markets permit tacit collusion among firms to a greater extent than anticipated when their capacity was first installed with the result that suppressing output now yields excess capacity. Once again the data would then show a positive correlation between concentration and excess capacity that should not be attributed to entry deterrence.

One way to deal with the unobservable differences across markets is to put in a "fixed effects" term, which amounts to letting the regression intercept be different for each market. These fixed effects terms will pick up all the differences between markets—observed or unobserved, unrelated to time. The bad news, though, is that this means that the identification of a concentration effect comes from the variation over time within a market and not from the differences in concentration across market. This variation is not sufficiently large to yield useful estimates if these "fixed effects" are included in the regression model of equation (12.9). Therefore, Conlin and Kadiyali (2006) turn to an alternative specification that looks at the relation between an individual firm's excess capacity and that firm's market share.

Specifically, using i to index firms; m to index market; and t to index time, Conlin and Kadiyali (2006) estimate the following regression:

$$\begin{aligned}\text{Excess Capacity}_{i,m,t} = {} & \text{Constant}_{m,t} + \gamma\,\text{Market Share}_{i,m,t} \\ & + \rho(\text{Share in Total Capacity of Related Hotels})_{i,m,t} \\ & + \eta(\text{Incumbent Expansion})_{i,m,t} + \theta(\text{Entrant Expansion})_{i,m,t} + u_{i,m,t}\end{aligned} \tag{12.10}$$

Table 12.3 Effect of market share on excess capacity in local texas hotels

Market Definition	*Market Share Estimated Coefficient*	*Standard Error*
County	0.4115*	(0.027)
County-Sector	0.177*	(0.035)
City	0.106*	(0.022)
City-Sector	0.157*	(0.300)

*Significant at 1% level.

The first term in equation (12.10) directly addresses the hypothesized effect. If large firms keep excess capacity as part of an entry deterring strategy, the estimate of γ will be positive. The other variables pick up: 1) whether or not the firm is affiliated with other firms in the market, e.g., Holiday Inn is affiliated with Holiday Express; 2) whether the firm is an incumbent that has recently expanded; or 3) whether the firm is an entrant that has recently expanded. Because the estimation is conducted at the firm level and there is a lot of variation in a firm's share of a specific market over time, this equation *can* be estimated using the fixed effects estimator. The results are shown in Table 12.3 below.

Here again, the effects are supportive of the use of excess capacity as an entry-deterring device. Excess capacity rises significantly with an increase in a firm's market share. Overall, the marginal effect of an increase of 10 percentage points in the firm's market share is an increase of 1.2 percentage points in a firm's excess capacity. While again, there may be other explanations behind these findings other than entry deterrence, the results in Table 12.3 when added to those in Table 12.2 offer fairly compelling evidence that entry deterrence is at least part of the explanation.

Summary

This chapter has investigated the ability of firms to maintain a dominant market position in their industry for a prolonged period of time. Both anecdotal and formal evidence indicate that such sustained market power is a widespread feature. In turn, this implies that the entry of new rivals who can compete away an incumbent firm's profits is not as powerful in the real world as it is suggested to be in basic microeconomic texts. Something permits an incumbent to preserve its market position and successfully defend itself against rival entry.

By itself, a finding that market structures have evolved in a manner that maintains or even strengthens the dominance of initial firms over time is not evidence of entry deterrence. Random processes such as Gibrat's Law suggest that asymmetrically dominated markets are the norm. Richer theoretical models such as Klepper's (2002), in which innovation becomes easier as firms get larger and more experienced, also yield oligopoly as their equilibrium outcome. Yet the additional evidence that when entry does occur it is on a small scale and often doomed to failure, along with the experiences that motivated the antitrust laws initially and the numerous court cases and anecdotal observations that have followed, all coalesce into a clear enough pattern that one cannot help but be suspicious that entry is being deterred. That suspicion can only be confirmed or denied, however, if one has a logically consistent model in which such predation is rational and formal evidence that supports that analysis.

Spence (1977), Eaton and Lipsey (1979), Dixit (1980), and Nalebuff (2004) are all examples of modern efforts to develop formal models of entry deterrence. These models hinge on the ability of incumbent firms to commit to a large output in the face of entry, typically by making a

substantial capital investment. Numerous case studies suggest that firms such as Alcoa and DuPont have used such entry-deterring tactics. Statistical documentation of this behavior as an empirical regularity is more difficult, but work such as Conlin and Kadiyali (2006) does suggest a clear linkage between market power and excess capital capacity, consistent with models of entry deterring behavior. Thus, there is reason to believe that such tactics are common among real-world firms. Still it must be recognized that it is often difficult to distinguish predation from normal competitive behavior.

In both theory and practice, there is a distinction between preventing the entry of new firms and driving existing ones out of business. In this chapter we have focused on the issue of entry deterrence, or predatory conduct, and done so in a setting of complete information. While some of these tactics will apply equally well to driving rivals out rather than just not letting them in, we will address explicit efforts to force rivals to exit in the next chapter. We will also extend our analysis of incumbent response to entry in the context of incomplete information.

Problems

1. Let the domestic market for small, specialized calculators and similar office equipment be currently served by one firm, called firm I. The firm has the following cost schedules: $\mathrm{TC}(q_I) = 0.025q_I{}^2$ and $\mathrm{MC}(q_I) = .05q_I$. Market demand is $P = 50 - 0.1Q$, and right now q is equal to q_I because the only firm in the market is the incumbent firm I.
   a. If the incumbent acts as a simple monopolist, what price will it charge and what level of output will it produce?
   b. Suppose now that a foreign producer of calculators is considering exporting to the US market. Because of transportation costs and tariffs this foreign firm faces some cost disadvantage vis-à-vis the domestic incumbent. Specifically the foreign firm's cost schedules are: $\mathrm{TC}(q_E) = 10q_E + 0.025$ and $\mathrm{MC}(q_E) = 10 + .05q_E$. Suppose that the incumbent firm is committed to the monopoly level of output. What is the demand curve faced by the potential entrant? Write it down. Facing this demand, what level of output will the foreign firm actually export to the domestic market? What will be the new industry price?
   c. To what level of output would the incumbent firm have to commit in order to deter the foreign firm from entering the market? (Hint: You must solve for output level $q*$ with the property that if the entrant believes that the incumbent will produce $q*$, then the entrant's profit-maximizing response will be to produce such that $= 0$.) What is the incumbent firm's profit?
2. Return to Problem 1. Suppose that the incumbent and the entrant instead will play a Cournot game if and when the entrant enters. What are firms' profits in this case? Is it reasonable to believe that the incumbent will try and commit to $q*$ in order to deter entry? Why?
3. Suppose that the inverse demand function is described by: $P = 100 - 2(q_1 + q_2)$, where q_1 is the output of the incumbent firm and q_2 is the output of the entrant. Let the labor cost per unit $w = 20$ and capital cost per unit be $r = 20$. In addition, let each firm have a fixed cost of $F_1 = F_2 = \$100$.
   a. Suppose that in stage one the incumbent invests in capacity $\overline{K}_1$. Show that in stage two the incumbent's best response function is $q_1 = 20 - q_2/2$ when $q_1 \leq \overline{K}_1$; and $q_1 = 15 - q_2/2$ when $q_1 > \overline{K}_1$.
   b. Show that the entrant's best response function in stage two is $q_2 = 15 - q_1/2$.
4. Return to Problem 3. Now show that if the incumbent commits to a production capacity of =15, the entrant will do best by producing 7.5 and earn a profit of \$12.5, while the incumbent earns a profit of \$125.
   a. Show that if the incumbent instead commits in stage one to a production capacity = 16 then the entrant's best stage two response is to produce

$q_2 = 7$, at which output the entrant does not earn a positive profit.

b. In light of your answer to 2(d), show that committing to a production capacity of 16, gives the incumbent a profit of \$348.

5. Two firms, firm 1 and 2, must decide whether to enter a new industry. Industry demand is described by $P = 900 - Q$, where $Q = q_1 + q_2, q_j \geq 0$. To enter the industry a firm must build a production facility of one of two types: small or large. A small facility requires an investment of \$50,000 and allows the firm to produce as many as 100 units of the good at a unit production cost of zero. Alternatively, the firm can pay \$175,000 to construct a large facility that will allow the firm to produce any number of units of output at zero unit cost. A firm with a small production facility is capacity constrained whereas a firm with a large facility is not. Firm 1 makes the entry decision first. It must choose whether to enter and, if it enters, what kind of production facility to build. After observing firm 1's action, firm 2 chooses from the same set of alternatives. If only one firm enters the industry then it selects a quantity of output and sells it at the corresponding price. If both firms are in the industry they compete as Cournot firms. All output decisions in the market stage are subject to the capacity constraints of the production facilities. The market lasts for only one period.
   a. Draw the extensive tree that represents the entry game being played between 1 and 2.
   b. What is the outcome? Does firm 1 enter and at what size? Does firm 2 enter and at what size?

6. Let the demand for hand-blown glass vases be given by $q = 70000 - 2000P$, where q is the quantity of glass vases consumed per year and P is the dollar price of a vase. Suppose that there are 1000 identical small sellers of these glass vases. The marginal cost function of such a seller is $\text{MC}(q) = q + 5$, where q is the firm's output.
   a. Assuming that each small seller acts as a price taker in this market derive the market supply curve, and the equilibrium price and quantity traded.
   b. Suppose that a new mechanized technique of producing vases is discovered and monopolized by some firm, call it firm B for "BIG." Using this technique, vases can be produced at a constant average and marginal cost of \$15 per vase. Consumers cannot tell the difference between vases produced by the old and the new technique. Given the existence of the fringe of small sellers what is the demand curve facing firm B?
   c. Facing this demand curve, what is the profit-maximizing quantity produced by firm B? What is the price that it sets and the overall amount of vases traded in the market?

7. There are ten consumers in the markets for widgets and gadgets. Consumer valuations for each good are positively correlated, as shown in the tables below, and consumers will buy at most one unit of either good. The incumbent has a monopoly in each product. Producing each incurs a marginal cost of \$40. There is also a fixed cost of \$20 associated with the production of each good.

Consumer	*Willingness to Pay For a Widget*	*Willingness to Pay For a Gadget*
1	\$10	\$10
2	\$20	\$20
3	\$30	\$30
4	\$40	\$40
5	\$50	\$50
6	\$60	\$60
7	\$70	\$70
8	\$80	\$80
9	\$90	\$90
10	\$100	\$100

   a. Show that the prices $P_{Widget} = P_{Gadget} = \$70$ will maximize the firm's profit if the goods are sold separately.
   b. Show that there is no incentive for the incumbent to bundle the goods and sell them as a package of one widget and one gadget.

c. Imagine that there is a potential entrant in the gadget market selling an identical product to the incumbent's and competing in price. If the entrant has a marginal cost of \$30 per unit and a fixed cost of \$20, can the entrant enter and compete successfully against the incumbent in the gadget market if the incumbent sells gadgets separately from widgets?

d. Show that if the incumbent sells widgets and gadgets only as a bundle of one unit of each good at a price of \$100 it will successfully keep the entrant out. Is this strategy profitable for the incumbent?

8. [Calculus] Suppose that two firms are in a race to enter a new market. For each firm, there is an advantage to taking time and perfecting its product because then consumers will pay more for it and it will be more profitable. However, there is also a disadvantage in waiting, in that this has an interest opportunity cost of r. Let the time to enter t vary from 0 to 1 (year), and denote the choice of firm 1's entry and firm 2's entry as t_1 and t_2, respectively. The (symmetric) profit functions are:

$$\pi^1(t_1, t_2) = \begin{cases} e^{(1-r)t_1}; & \textit{if } t_1 < t_2 \\ e^{\left(\frac{1}{2}rt_1\right)}; & \textit{if } t_1 = t_2 \\ e^{(1-t_2)-rt_1}; & \textit{if } t_1 > t_2 \end{cases}$$

$$\pi^2(t_1, t_2) = \begin{cases} e^{(1-r)t_2}; & \textit{if } t_2 < t_1 \\ e^{\left(\frac{1}{2}rt_2\right)}; & \textit{if } t_2 = t_1 \\ e^{(1-t_1)-rt_2}; & \textit{if } t_2 > t_1 \end{cases}$$

Show that the Nash equilibrium entry times are $t_1 = t_2 = 1/2$.

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Appendix

Wee present the formal analysis behind the Dixit (1980) model of entry prevention assuming the linear demand and cost relations given in the text.

Market inverse demand is given by $P = A - Q = A - (q_1 + q_2)$ where q_1 is the output of the incumbent and q_2 is the output of the entrant. Production of one unit of output by