cut price. (Technically, the model is one of signal jamming.) In our symmetric equilibrium, each firm charges price α in the first period. If the intercept is a, each firm i learns a perfectly by observing its first-period demand:

$$D_i^{\mathrm{A}} = a - \alpha + \alpha = a.$$

The second-period game is one of complete information; hence, the Bertrand equilibrium in the second period has both firms charging a.[21]

Suppose that firm i deviates and charges price $p_i^{\mathrm{A}} \neq \alpha$ in the first period. Firm j observes a demand of

$$D_j^{\mathrm{A}} = a - \alpha + p_i^{\mathrm{A}}.$$

Its perception $\tilde{a}$ of a, given by

$$a - \alpha + p_i^{\mathrm{A}} = \tilde{a} - \alpha + \alpha = \tilde{a},$$

is therefore erroneous. Thus,

$$\tilde{a}(p_i^{\mathrm{A}}) = a + (p_i^{\mathrm{A}} - \alpha). \tag{9.5}$$

In the second period, firm j believes it is playing a game of perfect information, with intercept $\tilde{a}(p_i^{\mathrm{A}})$, so it charges $p_j^{\mathrm{B}} = \tilde{a}(p_i^{\mathrm{A}})$. Using equation 9.5, we obtain the coefficient of "conjectural variations":

$$\frac{dp_j^{\mathrm{B}}}{dp_i^{\mathrm{A}}} = \gamma = 1.$$

A unit increase in the first-period price triggers a unit increase in the rival's second-period price.

To derive α, one proceeds as follows: Firm i, when it deviates, is not fooled about a. It therefore maximizes its second-period profit:

$$\max_{p_i^{\mathrm{B}}}[a - p_i^{\mathrm{B}} + \tilde{a}(p_i^{\mathrm{A}})]p_i^{\mathrm{B}}.$$

Thus,

$$p_i^{\mathrm{B}} = \frac{a + \tilde{a}(p_i^{\mathrm{A}})}{2} = a + \frac{p_i^{\mathrm{A}} - \alpha}{2}.$$

By the envelope theorem, the derivative of this second-period profit with respect to p_i^{A} is

$$p_i^{\mathrm{B}}\frac{d\tilde{a}}{dp_i^{\mathrm{A}}} = p_i^{\mathrm{B}}.$$

The expectation of this derivative with respect to a is thus

$$a^e + \frac{p_i^{\mathrm{A}} - \alpha}{2}.$$

In the first period, the expected present discounted profit of firm i is maximized. Thus, the sum of the first-period marginal profit

$$\frac{d}{dp_i^{\mathrm{A}}}[(a^e - p_i^{\mathrm{A}} + \alpha)p_i^{\mathrm{A}}]$$

and the second-period marginal profit is 0:

$$a^e - 2p_i^{\mathrm{A}} + \alpha + \delta\left(a^e + \frac{p_i^{\mathrm{A}} - \alpha}{2}\right) = 0. \tag{9.6}$$

In equilibrium, $p_i^{\mathrm{A}} = \alpha$, which together with equation 9.6 yields

$$\alpha = a^e(1 + \delta). \tag{9.7}$$

Each firm charges $a^e(1 + \delta)$ in the first period, rather than a^e (which would, on average, be charged under complete information about a, and which would be charged under incomplete information in a single-period model).[22]

Mailath's setup is closer than Riordan's to the Milgrom-Roberts model discussed in the next section, with observable prices and private information about cost. (The Mailath model is a signaling model.) The conclusions, however, are similar. This approach by no means justifies the static conjectural-variations approach, but it illustrates the positive effect of a firm's price on its rival's price.[23]

9.4 The Milgrom-Roberts Model of Limit Pricing

It has often been alleged that an established firm can discourage entry by charging a low price. Bain's (1949) concept of limit pricing was built around the idea that if there is a positive relationship between the pre-entry

21. The reaction curves are $p_i^{\mathrm{B}} = (a + p_j^{\mathrm{B}})/2$. By symmetry, $p_i^{\mathrm{B}} = p_j^{\mathrm{B}} = a$.

22. Here the second-order condition is satisfied. When a has a compact support, the global second-order condition may be harder to satisfy.

23. Under quantity competition, the conclusions are naturally reversed. For instance, in the Mailath model an increase in quantity signals a low cost and therefore a high quantity tomorrow. This induces the rival to curtail output tomorrow. As Riordan notes, one then gets negative conjectural variations.

price and the speed or degree of entry, the established firm indeed has an incentive to cut its price.[24]

Although Bain's view prevailed for thirty years, many economists felt uncomfortable about applying it to antitrust analysis. To condemn a firm for making consumers pay too little seemed paradoxical. More important, it was not clear how a low price could deter entry. As Bain mentioned, a low price must convey bad news to potential entrants about their profitability in the market.

One possibility is that the price of the established firm has commitment value. That is, the entrants expect the pre-entry price to prevail after entry. However, such a theory is not very convincing. Entry into many markets is a decision that covers a period of many months or years, whereas a price can often be changed within a few days or weeks. Consequently, any loss that a potential entrant may suffer from a low pre-entry price is negligible. Prices *per se* have only a short commitment value (Friedman 1979). Now, it may be the case that a low pre-entry price is associated with a high pre-entry capacity. The capacity may have a higher commitment value than the attached price. The source of the entry deterrence is then the incumbent's capacity rather than its price (see chapter 8).

In this section we will look at industries in which capacities do not necessarily have commitment value. As we will see, the incumbent firm may nevertheless lower its price when facing the threat of entry. The paper that is crucial to the reexamination of the doctrine of limit pricing (and, more generally, in drawing our attention to the implications of asymmetric information for antitrust analysis) is Milgrom and Roberts 1982a. A simplified version of the Milgrom-Roberts two-period model is given in the following subsection.[25]

9.4.1 A Model

There are two periods and two firms. Firm 1, the incumbent, is a monopoly at date 1 and chooses a first-period price p_1. Firm 2, the entrant, then decides to enter or stay out in the second period. If it enters, there is duopolistic competition in period 2. Otherwise, firm 1 remains a monopoly.

As in the static model of section 9.1, firm 1's cost can be low (with probability x) or high (with probability $1-x$). Let $M_1^t(p_1)$ denote the incumbent's monopoly profit when it charges p_1, where $t = \mathrm{L}$ or H (indicating low or high cost).[26] Let p_m^L and p_m^H, respectively, denote the monopoly prices charged by the incumbent when his cost is low and when it is high. We know from chapter 1 that $p_m^L < p_m^H$. Let M_1^L and M_1^H denote the incumbent's profit when it maximizes its short-run profit, depending on its type ($M_1^t \equiv M_1^t(p_m^t)$). Assume that $M_1^t(p_1)$ is strictly concave in p_1.

Firm 1 knows its cost from the start. Firm 2 does not know firm 1's cost. For simplicity (and following Milgrom and Roberts), assume that firm 2 learns firm 1's cost immediately after entering if it decides to enter; the second-period duopoly price competition, if any, is then independent of the price charged in period 1. Let D_1^t and D_2^t denote the two firms' duopoly profits when firm 1 is of type t. (D_2^t possibly includes entry costs.) To make things interesting, assume that firm 2's entry decision is influenced by its beliefs about firm 1's cost:

$$D_2^H > 0 > D_2^L. \tag{9.8}$$

That is, under symmetric information, firm 2 would enter if and only if firm 1's cost were high. The common discount factor is δ.

Because firm 1 prefers to be a monopoly ($M_1^t > D_1^t$, for $t = \mathrm{L, H}$), that firm clearly wants to convey the information that it has low cost. The problem is that it has no direct means of doing so, even if it indeed has a low cost. The indirect way is to signal by charging a low price, p_1^L. In our example, firm 1 may want to charge p_1^L even if it has a high cost. The loss in first-period monopoly profit may be offset by the second-period gain from remaining a monopoly. Does this mean that the potential entrant will stay out when observing p_1^L? It is not clear. A rational entrant, knowing that it is in the existing firm's self-interest to "lie" in this manner, will not necessarily infer that the incumbent has a low cost. In turn, the incumbent knows that the entrant knows about this incentive, and so on. As Milgrom and Roberts show, the correct way to analyze this dynamic game of incomplete information

24. For a model positing an exogenous relationship between pre-entry price and entry, see Gaskins 1971.

25. The analysis here follows section 6 of Fudenberg and Tirole 1986a.

26. Thus $M_1^t(p_1) = (p_1 - c_1^t)D_1^m(p_1)$, where $D_1^m(\cdot)$ is the monopoly demand.

is to solve for a "perfect Bayesian equilibrium" (see the Game Theory User's Manual).

There are two kinds of potential equilibria in such a model.[27] In a *separating* equilibrium, the incumbent does not pick the same first-period price when his cost is low as when it is high. The first-period price then fully reveals the cost to the entrant. In a *pooling* equilibrium, the first-period price is independent of the cost level. The entrant then learns nothing about the cost, and his posterior beliefs are identical to his prior beliefs (i.e., he still puts probability x on the cost's being low).[28]

Let us look for separating equilibria. There are two necessary conditions: that the low-cost type does not want to pick the high-cost type's equilibrium price, and vice-versa. We then complete the description of equilibrium by choosing beliefs that are off the equilibrium path (i.e., for prices that differ from the two potential equilibrium prices) and that deter the two types from deviating from their equilibrium prices. Thus, our necessary conditions are also sufficient, in the sense that the corresponding prices are equilibrium prices. In a separating equilibrium, the high-cost type's price induces entry. He thus plays p_m^H (if he did not, he could increase his first-period profit without adverse effect on entry). Thus, he gets $M_1^H + \delta D_1^H$. Let p_1^L denote the price of the low-cost type. The high-cost type, by charging this price, deters entry and obtains $M_1^H(p_1^L) + \delta M_1^H$. Thus, a necessary condition for equilibrium is

$$M_1^H - M_1^H(p_1^L) \geqslant \delta(M_1^H - D_1^H). \tag{9.9}$$

Similarly, the low-cost type must be maximizing his profit by choosing p_1^L. Because he could charge his monopoly price and get at worst $M_1^L + \delta D_1^L$ (at worst, p_m^L induces entry) and because in équilibrium he gets $M_1^L(p_1^L) + \delta M_1^L$, we must have

$$M_1^L - M_1^L(p_1^L) \leqslant \delta(M_1^L - D_1^L). \tag{9.10}$$

To make things interesting, assume that there is no separating equilibrium in which each type behaves as in a full-information context; i.e., the high-cost type would wish to pool if p_1^L were equal to p_m^L:

$$M_1^H - M_1^H(p_m^L) < \delta(M_1^H - D_1^H). \tag{9.11}$$

To characterize the set of p_1^L satisfying equations 9.9 and 9.10, we must make more specific assumptions on the demand and cost structures. Subsection 9.4.1.1 (which ought to be skipped in a first reading) does so. For our purpose it is sufficient to note that, under reasonable conditions, equations 9.9 and 9.10 define an interval $[\bar{\tilde{p}}_1, \tilde{p}_1]$, where $\tilde{p}_1 < p_m^L$. Thus, to separate, the low-cost type must charge a price sufficiently below his monopoly price so as to make pooling very costly to the high-cost type.

9.4.1.1 Derivation of the Interval of Separating Prices

The reason why it is more costly for the high-cost type to charge a low price is the so-called *sorting* or *single-crossing* condition (see the Game Theory User's Manual):

$$\frac{\partial[M_1^H(p_1) - M_1^L(p_1)]}{\partial p_1} > 0.$$

As we saw in section 9.2, this condition is satisfied here, because

$$\frac{\partial^2[(p_1 - c_1)D_1^m(p_1)]}{\partial p_1 \partial c_1} = -\frac{dD_1^m}{dp_1} > 0.$$

This condition ensures that the curves

$$y = M_1^L - M_1^L(p_1^L)$$

and

$$y = M_1^H - M_1^H(p_1^L)$$

cross once at most in the $\{p_1^L, y\}$ space. Next under some assumptions, the lower the incumbent's cost, the more he benefits from remaining a monopolist. Letting $D_1(p_1, p_2)$ denote the duopoly demand for firm 1 (notice that $D_1(p_1, +\infty) = D_1^m(p_1)$), letting $M_1(c_1)$ and $D_1(c_1)$ denote the monopoly and duopoly profits for cost c_1, letting p_1^d and p_2^d denote the equilibrium duopoly prices

27. Actually, there may exist a third kind, in which the incumbent uses a mixed strategy.

28. Bagwell (1985) analyzes whether the incumbent can signal its cost through alternative means (e.g., whether advertising can "crowd out" pricing as a signaling instrument). He finds that wasteful advertising is not used in equilibrium: Imposing a cost of \$1 for the high type to mimic the low type costs the low type less than \$1 when it lowers its price, but exactly \$1 when it advertises. For further elaborations (in particular, where advertising is not wasteful), see Bagwell and Ramey 1987.

(functions of c_1), and using the envelope theorem, we have

$$\frac{d[M_1(c_1) - D_1(c_1)]}{dc_1}$$

$$= \frac{d}{dc_1}\left(\max_{p_1}[(p_1 - c_1)D_1^{m}(p_1)] - \max_{p_1}[(p_1 - c_1)D_1(p_1, p_2^{d})]\right)$$

$$= -D_1^{m}(p_1^{m}) + D_1(p_1^{d}, p_2^{d}) - (p_1^{d} - c_1)\frac{\partial D_1}{\partial p_2}\frac{\partial p_2^{d}}{\partial c_1}.$$

The third term in this equality is presumably negative (because $p_1^{d} - c_1 > 0$, $\partial D_1/\partial p_2 > 0$, and—under mild conditions[29]—$\partial p_2^{d}/\partial c_1 > 0$). Thus, if the monopoly demand for firm 1 exceeds its duopoly demand, $M_1 - D_1$ decreases with c_1 and therefore

$$M_1^{L} - D_1^{L} > M_1^{H} - D_1^{H}.$$

This is the case for the unit-demand location model solved in chapter 7, where the monopoly demand was equal to the market size (i.e., was the maximum possible demand).

Using these derivations, we can obtain the interval $[\tilde{\tilde{p}}_1, \tilde{p}_1]$ from figure 9.2. $\tilde{p}_1$ is such that equation 9.9 is satisfied with equality; it is called the *least-cost* separating price because, of all potential separating prices, the low-cost type would prefer the one at $\tilde{p}_1$ (the closest to p_{m}^{L}).

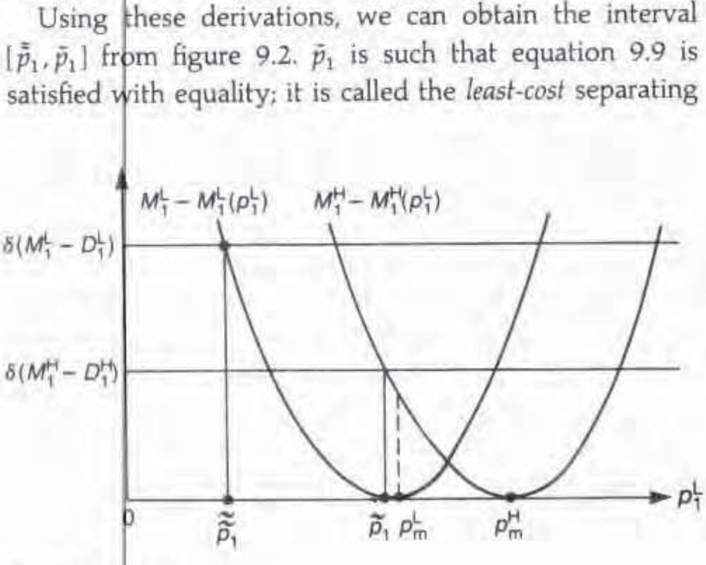

Figure 9.2

9.4.1.2 Analysis of a Separating Equilibrium

The necessary conditions studied in subsection 9.4.1.1 are also sufficient. Let the high-cost type choose p_{m}^{H} and let the low-cost type choose p_1^{L} in $[\tilde{\tilde{p}}_1, \tilde{p}_1]$. When a price that differs from these two prices is observed, beliefs are arbitrary (in an unexpected event, Bayes' rule does not pin down firm 2's posterior beliefs). The easiest way to obtain equilibrium is to choose beliefs that induce entry (this way, the two types will be little tempted to deviate from their presumed equilibrium strategies), so let us specify that when p_1 does not belong to $\{p_{m}^{H}, p_1^{L}\}$ the posterior beliefs x' are equal to 0 (firm 2 believes that firm 1 has a high cost).[30] Now, let us check that no type wants to deviate. The high-cost type obtains his monopoly profit in the first period and thus is not willing to deviate to another price that induces entry. Nor (according to equation 9.9) does he deviate to p_1^{L}. And similarly for the low-cost type. Thus, we have obtained a continuum of separating equilibria.[31]

It is generally felt that only one of these separating equilibria—the least-cost one—is "reasonable." Suppose that firm 1 charges p_1 in $[\tilde{\tilde{p}}_1, \tilde{p}_1)$. Such a price is dominated for the high-cost type; that is, the high-cost type is always better off charging p_{m}^{H} rather than p_1, whatever its expectations about the effect of price on entry. At worst, p_{m}^{H} triggers entry, and at best p_1 deters entry. Even if p_1 deters entry, the high-cost type makes more profit charging p_{m}^{H}, on the basis of equation 9.9 and the concavity of the profit function:

$$M_1^{H} + \delta D_1^{H} > M_1^{H}(p_1) + \delta M_1^{H}.$$

Thus, firm 2, when observing p_1, should not believe that firm 1 has a high cost. That is, p_1 should deter entry. This implies that the low-cost firm, to signal its type and deter entry, need not charge less than $\tilde{p}_1$.

29. See chapter 8.

30. Whether these beliefs (which are consistent with Bayes' rule) are "reasonable" will be discussed below.

31. This continuum of separating equilibria exists for any $x < 1$. For $x = 1$, however, the low-cost firm plays its monopoly price, p_{m}^{L}. Thus, a tiny change in the information structure may make a huge difference. A very small probability that the firm has a high cost may force the low-cost firm to lower its price discontinuously in order to signal its type. Games of incomplete information (which include games of complete information) are very sensitive to the specification of the information structure.

To summarize this rather long analysis: There exists a unique "reasonable" separating equilibrium. The high-cost type charges its monopoly price and allows entry. The low-cost type charges the highest price $\tilde{p}_1$ such that the high-cost type's first-period loss of charging $\tilde{p}_1$ weakly exceeds its gain from deterring entry. Firm 1 reduces its price from p_m^L to $\tilde{p}_1$ because of the asymmetry of information. The following conclusions hold for this separating equilibrium:

Conclusion 1 Despite the fact that the incumbent manipulates his price, the entrant is not fooled. He learns the incumbent's cost perfectly. Entry occurs exactly when it would have occurred under symmetric information.

Conclusion 2 Even though the incumbent does not fool the entrant, he engages in limit pricing; the low-cost type would be mistaken for the high-cost type if it did not sacrifice short-run profits to signal its type.

Conclusion 3 Social welfare is higher than under symmetric information. The second-period welfare is not affected because entry is not affected. First-period welfare is generally increased because the low-cost type reduces its price.

Though it would be premature to conclude that limit pricing always increases welfare (see below), such a separating equilibrium shatters any illusion that low pre-entry prices obviously reduce welfare.

9.4.1.3 Pooling Equilibria

The existence of pooling equilibria hinges on whether the condition

$$xD_2^L + (1-x)D_2^H < 0 \tag{9.12}$$

is satisfied.

Assume that condition 9.12 is violated (with a strict inequality—for simplicity, we will not consider the equality case). Then, at the pooling price, firm 2 makes a strictly positive expected profit if it enters (as posterior beliefs are the same as prior beliefs). This means that entry is not deterred, so that the two types cannot do better than to choose their static monopoly prices. As these prices differ, no pooling equilibrium can exist.

Assume, therefore, that condition 9.12 is satisfied, so that a pooling price p_1 deters entry. A necessary condition for a price p_1 to be a pooling-equilibrium price is that none of the types wants to play its monopoly price. If one of them were to do so, it would at worst allow entry. Therefore, p_1 must satisfy condition 9.10 and the analogous condition for the high-cost type:

$$M_1^H - M_1^H(p_1) \leqslant \delta(M_1^H - D_1^H). \tag{9.13}$$

Again, the set of prices p_1 that satisfy both condition 9.10 and condition 9.13 depends on the cost and demand functions. Let us simply note that, from condition 9.11, there exists an interval of prices around p_m^L that satisfy these two inequalities.

Now it is easy to see that if p_1 satisfies conditions 9.10 and 9.13, p_1 can be made part of a pooling equilibrium. Suppose that whenever firm 1 plays a price differing from p_1 (an off-the-equilibrium path price), firm 2 believes that firm 1 has a high cost. Firm 2 then enters, and firm 1 might as well play its monopoly price. Thus, from conditions 9.10 and 9.13, none of the types would want to deviate from p_1.[32]

Let us consider the pooling equilibrium in which both firms charge the low-cost monopoly price p_m^L. It is easy to see that some of our conclusions for the separating equilibrium are reversed:

Conclusion 1' The incumbent manipulates its price in a way that does not reveal cost information. There is less entry than under symmetric information (entry is always deterred, and not only with probability x).

Conclusion 2' The low-cost type charges its monopoly price. The high-cost type engages in limit pricing to deter entry.

Conclusion 3' The consequences of asymmetric information for welfare are ambiguous. First-period welfare is, in general, increased, because the high-cost type lowers its price. But there is less entry, which, in general, lowers second-period welfare.

32. We will not consider here how restrictions on beliefs can eliminate some (or, possibly, all) equilibria. (One way to eliminate equilibria is to use the Cho-Kreps criterion—see subsection 11.6.2.) For more detail in the context of the limit-pricing game, see Cho 1986.

9.4.2 Discussion

The Milgrom-Roberts model shows that limit pricing does occur, but that it is not necessarily harmful.

It turns out that the conclusions are sensitive to the data of the problem. This means that the industrial economist must have an intimate knowledge of the industry in question before drawing definite conclusions about limit pricing. First, pooling and separating equilibria differ in their positive and normative consequences. Second (as section 9.3 suggests), if the incumbent accommodates entry and if its cost is not learned by the entrant at the entry date, the incumbent charges more than the monopoly price. Thus, if the incumbent is unsure whether he will deter or accommodate entry (for instance, because he does not know the entry cost), it is not clear whether he will charge more or less than the monopoly price. Third, the previous model assumed that the incumbent's cost was unrelated to the entrant's. Consider the other polar case, in which the entrant's cost c_2 is equal to the incumbent's cost c_1 but the entrant does not know it before entering. Firm 2's duopoly profit is then a function $D_2(c_1)$. For many specifications of second-period competition, D_2 is a decreasing function of c_1. (A symmetric decline in cost tends to increase both firms' profits.) Thus, to deter entry, the incumbent must signal a *high* cost and therefore charge a price above the monopoly price in the first period (Harrington 1985).

As in chapter 8, the principles established for the deterrence of entry also apply to the inducement of exit (*predation*). Salop and Shapiro (1980), Scharfstein (1984), and Roberts (1986) have extended the Milgrom-Roberts approach to formalize post-entry predation. In their model, the established firm preys on an entrant who faces a cost of reentry in order to convey that it has bad news about the entrant's future profitability.[33] Thus, the model of limit pricing can, with small changes, be reinterpreted as one of predatory pricing.

The welfare analysis of the limit-pricing model has implications for the predation model. Suppose that two firms compete in period 1, and that at the end of period 1 firm 2 (still called the "entrant") decides whether to exit on the basis of its observation of firm 1's price. (The only difference with the limit-pricing model is that the entrant is in at date 1.) In a separating equilibrium, the entrant is not fooled, and lower prices improve the first-period welfare. We already noticed that welfare may go down if the equilibrium is a pooling one; here we have another reason to be circumspect about the benefits of limit pricing. Introduce another period (period 0), in which the entrant decides whether or not to sink an entry cost. Even if the equilibrium is separating, so that the entrant will not be fooled in period 1, the incumbent's price is lower than under symmetric information, which reduces the entrant's expected profit. Thus, in period 0, the prospective entrant is less likely to enter.[34] Predation may be *ex ante* detrimental, even though it is welfare improving when it takes place (in period 1).

More generally, the Milgrom-Roberts model and its variants offer a framework for discussing tests of predatory behavior.[35] As in the case of "barriers to entry," it is difficult to come up with a satisfactory definition of "predation." The intuitive notion refers to low prices (or high advertising levels) that are meant to induce a rival's exit so as to assure the remaining firm of higher profits in the future. As in the taxonomy of chapter 8, we can decompose the effect of a predator's action into two components. The first indicates how this action directly affects the predator's profit, if we take the rival's behavior (in particular, the exit decision) as fixed. The second reflects the influence of this action on the rival's behavior (a strategic effect). The predator, for instance, realizes that a low price may depress the rival's assessment of profitability in this market and may thus induce exit. One may define predation as the reflection of this strategic effect on the predator's behavior. These theoretical considerations, however, leave two issues open. The first is semantic: As we have seen, predation in the above sense is not necessarily socially harmful. As the word usually carries a negative connotation, this raises the issue of whether we want

33. A signal-jamming version of the same idea is provided in Fudenberg and Tirole 1986b. There, an established incumbent (without superior information) secretly cuts its price to mislead the recently entered firm to believe that its intrinsic profitability is low, thus trying (but not succeeding) to induce exit. As in Milgrom and Roberts' separating equilibrium, the entrant sees through the incumbent's strategy and is not fooled. An example of signal-jamming predation is given in example 4 in section 11.5.

34. The entrant stays out for a larger range of entry costs.

35. See Ordover and Saloner 1987 for a good discussion of these tests.

to use it in cases where the strategic behavior increases welfare. The second issue is operational: As in chapter 8, it may be hard to disentangle the two components of the effect of the action on the predator's profit. A low price or a high level of advertising may simply be a competitive ("innocent") behavior intended to maximize profit (where competition is taken as given). But it may also have the strategic purpose of inducing exit. This brings us to the legal definitions of predation.

The early tests of predatory behavior (Areeda and Turner 1975; Posner 1976) were based on cost. For instance, the Areeda-Turner test, which has been embraced by U.S. courts in several antitrust cases, holds that a price below the short-run marginal cost should be unlawful and that the short-run marginal cost can be approximated by the average variable cost. There have been many discussions as to what is a good surrogate for short-run marginal cost, but the most fundamental criticism of the Areeda-Turner test is that the comparison of price and marginal cost may not be related to predatory pricing. As Joskow and Klevorick (1979, pp. 219–220) have insisted, what is important is the trade-off between the sacrifice of current profit and the gain from monopolization:

Predatory pricing behavior involves a reduction of price in the short run so as to drive competing firms out of the market or to discourage entry of new firms in an effort to gain larger profits via higher prices in the long run than would have been earned if the price reduction had not occurred.

For instance, in the Milgrom-Roberts model, predatory pricing can involve prices above or below the marginal cost. The signal conveyed to the entrant or the prey about its future profitability matters as much as the predator's current sacrifice of profits.

Although predatory behavior can be demonstrated within an abstract model, deriving empirical tests for antitrust analysis is difficult indeed. How can one measure predatory intent if the predatory price bears no systematic relation to cost?

One possibility is to look at the incumbent's intertemporal price path. For instance, suppose that the incumbent firm cuts its price when entry occurs. This might indicate predatory behavior. However, the incumbent's residual demand curve falls when a competitor enters, which may call for a lower price independent of predatory intent (Williamson 1977). Joskow and Klevorick call this labeling of a truly competitive price cut as predatory a "type-I error." Conversely, suppose that the incumbent does not lower his price when entry occurs. This does not mean that the incumbent does not engage in anticompetitive behavior. The incumbent may have been practicing limit pricing (charging a low price) before entry, and—having been unsuccessful in deterring entry—may have felt no need to cut his price further. Thus, the time-series analysis of the incumbent's price may lead to a "type-II error," in which predatory behavior goes undetected. More generally, any test will have to face these two types of errors.

One drawback of games of incomplete information[36] is the multiplicity of equilibria. In the limit-pricing game, what should firm 2 believe when it observes a price p_1 that is not an equilibrium price? Because such an event has zero probability, Bayes' rule cannot be applied. In contrast with the well-defined beliefs that characterize equilibrium strategies, any posterior beliefs are consistent with Bayesian updating.[37] Now, this engenders a large multiplicity of beliefs. Suppose that we do not want p_1 to be chosen by some type of firm on the equilibrium path. If observing p_1 is indeed an off-the-equilibrium-path event, we can choose posterior beliefs $x'(p_1)$ following p_1 as we like; so let us assume that $x'(p_1)$ is very unfavorable to the incumbent. (Here $x'(p_1) = 0$, so p_1 triggers entry.) Then, depending on p_1, it is quite possible that no type wants to choose p_1. This fulfills our earlier assumption that p_1 was off the equilibrium path. One way to reduce the multiplicity—a way that has been explored intensely in game theory in recent years—is to impose some "reasonable" restrictions on beliefs following a zero-probability event. (We used such a restriction earlier to

36. See Milgrom and Roberts 1987 for a fuller discussion of various limits of this approach.

37. Suppose that the low type chooses p_1 with probability α^L and that the high type does so with probability α^H. Bayes' rule determines posterior beliefs x' through the formula

$$x'[x\alpha^L + (1 - x)\alpha^H] = x\alpha^L.$$

For a positive-probability event ($\alpha^L + \alpha^H > 0$), x' is uniquely defined. For a zero-probability event ($\alpha^L = \alpha^H = 0$), any x' in [0, 1] is admissible.

single out a unique equilibrium among separating equilibria; for further "refinements," see the Game Theory User's Manual and the references therein.) Another route, taken by Matthews and Mirman (1983) and Saloner (1981), is to assume that the incumbent's first-period price[38] is observed by the entrant with some noise. For instance, the entrant could observe $\tilde{p}_1$ where $\tilde{p}_1$ follows some conditional distribution $F(\tilde{p}_1 | p_1)$. If the support of F is all of R^+, for instance, there are no longer zero-probability events, and Bayes' rule retains its power. Assuming that the incumbent's output is a strictly decreasing function of his marginal cost, Saloner shows that every type of incumbent firm engages in limit pricing (i.e., produces more than the monopoly output).

Saloner also extends this model to more than two periods. In each period, the entrant receives a noisy version of the price and decides whether to enter. Intuitively, the entrant should enter if and only if the price exceeds some history-dependent threshold. The entrant may want to wait to obtain more precise information, and therefore entry is in general delayed relative to the full-information case. However, as in the Milgrom-Roberts model, the limit-pricing behavior does not bias the delay in a clear direction, as it is anticipated by the entrant. (The delay is due to the noise and the entrant's willingness to learn.)

9.5 Predation for Merger

The purpose of this section and the next is to apply the logic of section 9.4 to predatory behavior. As we saw in that section, the limit-pricing model can be reinterpreted as a predation model. However, several economists close to the Chicago School—McGee (1958, 1980), Telser (1966), and Bork (1978)—have argued that it cannot be rational to engage in predatory pricing in order to induce exit. Their argument is that merging with the rival (if legal) is a superior way to realize monopoly power. Competition—especially predatory competition—destroys industry profit, and the rivals have incentives to avoid it. For instance, the predator could make an offer to the prey that would be preferred by both to the predatory outcome. Hence, episodes of price cutting must be attributed to other, more innocent considerations, such as a fluctuation in demand or cost or a normal reaction to a decline in the residual demand curve due to entry.

Before games of asymmetric information became standard practice, Yamey (1972) criticized the above argument on two grounds. First, the predator may face potential entry in the market in question or in other markets in which it operates. If it does not fight in the market in question but prefers to take over its rival, it may be perceived as a weakling (for instance, a high-cost firm that is afraid to engage in a price war). This may encourage other firms to enter (possibly in the other markets), because they anticipate that, rather than being preyed upon, they will make profits in those markets or else will be bought out at advantageous prices. Second, the buyout price of the prey may not be independent of the predator's pre-merger market behavior. Clearly, these two objections are linked to private information and reputation. Under complete information, predatory pricing would not affect the perceived profitability of the prey or of other potential entrants.[39]

We will take up Yamey's first argument in section 9.6. We will now examine his second argument in light of Saloner's (1987) work. But before doing so, let us see how these two arguments can be motivated with examples taken from the great merger wave of 1887–1904 (a time in which there were few impediments to horizontal mergers—see Scherer 1980, pp. 121–122).

Between 1891 and 1906, the American Tobacco Company and two affiliated corporations acquired 43 of their competitors. American Tobacco engaged in predatory pricing (sometimes of the signal-jamming variety—secretly controlled subsidiaries, known as "bogus independents," secretly cut prices, so that the rivals would attribute the decline in their profits to intensified and enduring competition or to declining demand). Burns (1986) offers evidence that predatory pricing considerably reduced American Tobacco's cost of acquiring its competitors (both those that were victims of predation and the competitors not preyed upon yet, who sold peacefully). Another famous case is that of the Standard Oil Company of New Jersey.

38. The authors cited actually use quantity rather than price.

39. "A bout of price warfare initiated by the aggressor, or a threat of such activity, might serve to cause the rival to revise its expectations, and hence alter its terms of sale to an acceptable level." (Yamey 1972, p. 130)