13.5 PREDATION AND ANTITRUST POLICY

In the wake of the Great Depression—a period of falling prices and many small firm bankruptcies—and with the history of the aggressive tactics of firms such as Standard Oil and NCR still fresh, it was perhaps natural that a wide consensus formed that predatory pricing was widespread and harmful. The most visible manifestation of that view was the passage of the Robinson-Patman Act of 1936 which, among other things, prevented selective price discounts by large firms that would disadvantage smaller firms. Over time however, this legislation was seen as less protective of competitive markets and more protective of specific competitors against more efficient rivals. Subsequently, against a history of cases such as *Utah Pie*, the work of McGee (1958, 1980), Koller (1971), Posner (1976), Bork (1978), Easterbrook (1984), and others of the Chicago School reflected a necessary corrective. Many firms achieve dominance not because of predation but because of their superior competitive skill. Hence, policies that constrain "bigness" would have adverse incentive effects on competitive behavior. A corollary to this view is that market dominance will not persist if it is due to any factor not related to superior skill or efficiency. Indeed, these very arguments were later made by Microsoft during its 1998–2001 trial and appeal. As a result of the force of these arguments, the Chicago School perspective on predatory behavior became increasingly influential. It received an official blessing in the 1986 *Matsuhita* case when the Supreme Court wrote, "For this reason, there is a consensus among commentators that predatory pricing schemes are rarely tried, and even more rarely successful."[16] A few years later in the *Brooke* case of 1993, the Court went even further and outlined stringent evidentiary standards that had to be met before a predation claim would be supported.[17]

The Brooke Group (also known as Ligget) was a small cigarette manufacturer that began selling a generic brand in 1980, at prices well below those of the major brands. When consumers responded favorably to the introduction of these cheap cigarettes, Brown & Williamson and other large tobacco companies responded with vigorous price cuts. In its effort to undersell Brooke, it seems clear that Brown cut prices so low that it sustained millions of dollars of losses over a period as long as a year or more. Ultimately, however, Brooke could not keep pace. It raised the price on its cigarettes. Almost immediately thereafter, Brown & Williamson and other cigarette manufacturers did the same.

The Supreme Court did not find the foregoing evidence conclusive. In the wake of the Chicago School revival, the Court had moved to a view that there was an economics consensus that predatory pricing was irrational. The Court did, however, take the opportunity to establish two broad requirements for the successful prosecution of a predatory pricing case. The first was evidence of selling below some measure of cost. The second and really new element introduced by the court was evidence that the predator had a reasonable expectation of recouping the losses endured during the predatory period. Just how strong the new requirements were can be seen in the fact that there was not one successful prosecution of predatory action in the first forty cases that followed the Brooke decision. It was not until the important case of Microsoft that there was a finding of criminal guilt.

In our view, the consensus to which the Supreme Court referred in *Matsuhita* no longer exists—if it ever did. Commitment via capacity expansion, asymmetric information, and

[16] *Brooke Group v. Brown & Williamson Tobacco* 509 U.S. 209 (1993). Interestingly enough, Brooke actually won the initial jury trial but lost in subsequent appeals to the federal courts.

[17] See Scherer's (1976) exchange with Areeda and Turner (1976) on this and other points.

contractual exclusions are all features that can be combined to make a coherent argument for the rationality of predatory actions. Here, the reputation effects of successful predation in one market are particularly important. In measuring the ability of a firm to recover its losses, one has to include in the calculations all the profits secured by the deterrent effect that the firm's reputation has on other would-be entrants in other markets and time periods.

However, the Court's statement of necessary evidence does speak to an important issue. The recognition that predation can be rational and can happen does not carry any clear policy implications unless we have a clear standard by which predatory actions can be identified and distinguished from conduct that is truly procompetitive. Any entry will generally evoke some reaction from the incumbent firms. Typically, this may come in the form of lower prices or other expanded consumer benefits. Most such responses are not predatory in nature. To the contrary, they are exactly the conduct that we expect and hope that markets will promote. Similarly, when any firm, large or small, first comes into a market as a new entrant, it may want to set a low initial price, lower than the short-term, profit-maximizing one, as a way to induce consumers to forego their usual brand and try the entrant's relatively unknown product. Once established, the firm may then raise price. Clearly, the intent of this kind of promotional pricing is not to drive a rival from the market. Yet it may be difficult empirically to distinguish this pricing strategy from predatory pricing.

In other words, to the extent that antitrust enforcement seeks to prevent predatory practices, policy makers need to create workable legal standards that are able to distinguish procompetitive from anticompetitive conduct. Ideally, we would like such policy to be governed by a simple rule that could be used to detect the presence of predation. This would permit all parties to understand just what is and what is not legal. Yet in the area of predation simple rules rarely work.

Of the various rules that have been proposed, the most famous is that of Areeda and Turner (1975), which essentially finds any price to be predatory if it is below the firm's short-run average variable cost standing in as a proxy for marginal cost. Unfortunately, it is not a very good proxy. In actual practice, average variable cost can be significantly less than short-run marginal cost so that a firm could set a price below its current marginal cost yet still above its average cost. In so doing, the firm would be acting within the legal range permitted by the Areeda and Turner rule even though a price below short-run marginal cost would likely be judged as predatory by many economists. Hence, as Scherer (1976) was quick to point out, the use of the average cost standard could still permit serious predation.[18] Moreover, if there are important learning curve effects so that average cost falls with a firm's cumulative production over time (as opposed to scale economies in which average cost falls with the volume of production per unit of time), predation can occur by means of a vigorous output expansion without prices ever falling below cost.[19]

Another problem is that the rule ignores the strategic aspect of predatory pricing. To take a simple example, consider a market in which there is one firm operating as a monopoly. Suppose that if a new firm enters it will produce an identical good to that of the monopolist and that the game is one of Bertrand or price competition. As we saw in Chapter 10, the equilibrium of this game is that prices fall immediately to their marginal cost. By Areeda and Turner's rule, this would not be predatory. Yet if the entrant foresees this outcome, the existence of any sunk entry cost will be enough to induce it to stay out. Here again,

[18] See Cabral and Riordan (1997) for an elaboration of this point.

[19] See, for example, his decision in *Barry Wright Corporation v. ITT Grinnell Corporation, et al.*, 724F. 2d 227 (1st Cir. 1983).

the Areeda and Turner rule might permit entry-deterring behavior. Whenever the threat of "cutthroat pricing" is sufficiently credible that it never is actually used, the evidence Areeda and Turner look for will not be found.

Despite its shortcomings, the Areeda and Turner rule has been applied in many US antitrust cases. It has been frequently relied upon by Supreme Court Justice, Stephen Breyer. It was also used to exonerate IBM against predatory price-cutting charges in *California Computer Products, Inc., et al. v. International Business Machines* [613 F. 2d 727 (9th Cir. 1979)]. Perhaps the clearest statement is that of Judge Kaufman who, in *Northeastern Telephone Company v. American Telephone and Telegraph Company et al.*, [651 F. 2d 76 (2nd Cir. 1981)], wrote: "We agree with Areeda and Turner that in the general case, at least, the relationship between a firm's prices and its marginal costs provides the best single determinant of predatory pricing."

Nevertheless, the weaknesses in the Areeda and Turner rule have led many economists to propose modified alternatives. Some of these are like the Areeda and Turner approach in that they focus essentially on the behavior of a single variable. Baumol (1979), for example, focuses primarily on the behavior of the incumbent's price before entry and after exit of a rival. Essentially, this rule requires that any price reduction by a dominant firm in the face of entry be required to be "quasi-permanent," say for a period of five years. If the price reduction that entry induced is quickly reversed following the entrant's exit, Baumol's (1979) rule would find the pricing behavior predatory.

In a later updating of this work, Baumol (1996) also suggests comparing the predator's price with a measure of Average Avoidable Cost (AAC). AAC is a measure of the cost that the alleged predator could have avoided had it not engaged in the predatory increase in output. Thus, if the predatory action lasted for a year, AAC would be the total amount of extra costs incurred in that year divided by the extra quantity produced. In a similar vein, Williamson (1977) suggests looking at the incumbent's *output* before and after entry. The idea is that a rapid expansion of output after entry would be a sign of possible predation. This rule has two advantages. First, because of the suspicion raised by expansion after entry, the incumbent might well expand output earlier. In turn, this eliminates some of the monopoly distortion that would otherwise occur when the incumbent is alone in the market. Second, Williamson's rule may also prevent capacity expansion as an entry-deterring strategy by making the threat to expand once entry is no longer credible.

While both the Baumol (1979) and Williamson (1977) rules are insightful, both are also limited by focusing on a single variable to indicate predation. As we have emphasized, predatory conduct is part of an often complicated corporate strategy. As a result, it is unlikely to be reflected accurately in the behavior of a single variable. The Dixit (1980) model of capacity deterrence does not involve pricing at all and so would go undetected by both the Areeda-Turner and the Baumol tests. Similarly, Williamson's test would not prevent deterrence by preemption. None of these tests involve any consideration as to whether the strategic environment actually permits predation.

Joskow and Klevorick (1979) were among the first to suggest a more complete assessment of alleged predation within a strategic framework. Their rule combines the separate criteria mentioned above—below-cost pricing, output expansion, and price reversal—but requires as well that there be evidence that such actions were or at least could have been conceived as part of an overall strategy. In particular, Joskow and Klevorick (1979) propose to examine company documents to determine whether or not a firm was intentionally pursuing the aggressive policies. These authors would also examine the industry's structural features to see whether the conditions for predatory pricing exist.

Ordover and Willig (1981) and Bolton, Brodley, and Riordan (2001) also try to present a comprehensive framework for evaluating predatory accusations. The Ordover and Willig (1981) paper is important for its clear and modern definition of predatory conduct as any action for which the profitability is dependent on driving the rival out or preventing it from entering in the first place. In this view, predatory pricing is but one of a number of predation tactics. Both papers argue that an important first step is to check the market structure for the preconditions necessary to make predation worthwhile. The structural conditions so identified are that the accused predator really has significant market power and that entry be difficult so that if a rival is forced to exit, it is not subsequently replaced. Brodley, Bolton, and Riordan (2001) also argue that recoupment can be demonstrated by relating the predator's actions to a clear and evidence-supported strategy of predation. In the case of predatory pricing, these authors would rely on an Average Avoidable Cost measure as a benchmark.

None of the proposed predatory standards is simple or easily translated into a courtroom proceeding. The difficulty of distinguishing between good, fierce competition, on the one hand, and predatory efforts, on the other, is substantial. Moreover, as tough as this distinction is to make in the case of pricing, it may be even more difficult to achieve in considering other actions.

For example, consider the alleged predatory product innovations key to two well-known cases, *Telex v. IBM*, and *Berkey v. Kodak*. In the former, the issue at hand was the claim by Telex (and others) that IBM, which at the time admittedly controlled the market for mainframe computers but faced serious competition in markets for peripheral equipment, began to develop new equipment designs so that only new IBM peripherals were compatible with IBM mainframes (a tying arrangement). In the *Berkey* case, Berkey was a photo-finisher and camera manufacturer that claimed that Kodak should have given it advance notice of Kodak's introduction of a new 110 camera film so as to permit Berkey to redesign its cameras and remain viable in the market. In both cases, the courts eventually ruled against the plaintiffs and in favor of IBM and Kodak, respectively. There is perhaps good reason to believe that the technological alterations reflected in these two cases truly were motivated by predatory considerations. However, there is also a legitimate fear that punishing such actions could have a chilling effect on all innovation.

13.6 EMPIRICAL APPLICATION: ENTRY DETERRENCE IN THE PHARMACEUTICAL INDUSTRY

We noted that legal cases concerning predatory and entry deterring behavior often founder for lack of a clear standard defining predation. It is equally difficult to find clear evidence of such efforts in formal econometric studies. To be sure, the case histories such as Weiman and Levin (1994) concerning AT&T and the Brevoort and Marvel (2004) paper studying NCR offer clear specific examples. In a widely-cited paper on shipping cartels, Scott-Morton (1997) does find some formal evidence that established cartels in the late 19th and early 20th century engaged in predatory pricing to deter new shipping entrants, especially when the entrants were small and/or had poor financial resources. However, in another paper, Scott-Morton (2000) Morton finds very little statistical evidence that pharmaceutical firms successfully use advertising to deter generic entry as the end of the incumbent's patent nears.

The unfortunate truth is that the formal econometric requirements necessary to identify consistently any systematic predatory behavior across a set of market data points are fairly

Reality Checkpoint

Cut-rate or Cutthroat Fares?

In 1994, Sun Jet Airlines began offering service between Dallas-Fort Worth airport and a select few other cities including Tampa, Florida, and Long Beach, California. Its entry was subsequently followed by that of Vanguard Airlines flying between Dallas and Kansas City, and Western Pacific offering flights between Dallas and Colorado Springs. All three airlines are small startup carriers whose operating costs are widely recognized to be well below those of the major, established airlines. Indeed, it was this cost advantage that gave these small startups their only hope of surviving in the Dallas-Fort Worth market. This is because the Dallas-Fort Worth airport is a central hub for American Airlines. American carries 70 percent of all the passengers who travel from any city nonstop to Dallas and 77 percent of all those nonstop passengers originating in Dallas. It has concessions from local businesses and has already sunk the costs necessary to operate its gates, ticketing desks, and so on. Internal documents obtained from American by the Justice Department reveal that these and other advantages made the firm confident that its dominance would not be challenged by another major airline. However, those same documents suggest that American was concerned about the entry of low-cost startups, especially after observing how much market share such firms had taken from other major carriers at their hub airports.

American responded aggressively to the three startups. It greatly expanded its flight offerings in the challenged markets and lowered its fares. In each of the three markets shown, this strategy ultimately led the startup to exit the market. Immediately thereafter, American cut its flights and raised fares back to or above earlier levels. This is shown for the case of three markets in the table below.

Was this a case of predatory pricing? The Justice Department thought so. It claimed that during the battle with the startups, American lost money on each flight. The actual losses are claimed to be even greater because to offer the additional flights, aircraft were diverted from profitable routes to these unprofitable ones. American won an initial decision in district court. In July 2003, a three-judge Appeals Court upheld the lower court's decision.

Source: D. Carney and W. Zellner, "Caveat Predator: The Justice Department is Cracking Down on Predatory Pricing," *Business Week*, May 22, 2000, p. 116.

	Before Entry		*During Conflict*		*After Exit*	
	# Daily Flights	*Price*	*# Daily Flights*	*Price*	*# Daily Flights*	*Price*
Kansas City	8	$108	14	$80	11	$147
Long Beach	0	—	3	$86	0	—
Colorado Springs	5	$150	7	$81	6	$137

demanding. One reason for this is that such work must somehow identify cases where an incumbent both regarded entry as a real threat *and* felt that there was a way to prevent it. Suppose, for instance, that the data set includes two kinds of markets. One type is characterized by a high likelihood of entry by several new firms and that by taking a costly action X the incumbent can reduce the number of entrants. The other market type is characterized by a very low probability of entry and by one new rival at most. Finally, suppose that post-entry competition is Cournot so that the fewer new entrants the better from the viewpoint of the incumbent.

In such a setting, we may find that incumbents only take action X in the first type of market because entry is so unlikely in the second kind of market that incurring the cost of action X is not worthwhile. If this is so, the data will be divided into two groups. In one set of cases, the incumbent takes action X and there is some entry (though less than otherwise would have been the case). In the other set of cases, the incumbent does not take action X, yet there is no entry. Thus, on balance, the data will show that there is *more* entry when the predatory tactic X is used than when it is not. Unless care is taken to identify such markets *a priori*, it will be hard to conclude from such data that predation is a serious threat.

Another difficulty that the researcher must overcome is identifying the entry-deterring strategy. This too is trickier than it may at first appear. Consider the first-mover, consumer learning-by-doing model of Gabszewicz, Pepall, and Thisse (1992) discussed in Chapter 11. Recall that in the first period of that model when the incumbent is alone, the incumbent prices low to "buy up" a cohort of customers who will be loyal to its product after the second-period entry of a rival because these customers have learned how to work with the incumbent's brand. On the one hand, then, such aggressive pricing may seem as if it deters entry because it limits the number of customers for whom the later entrant can compete. On the other hand, however, the fact that it has such a loyal and price-insensitive cohort encourages the incumbent to charge a high price when entry occurs, and this allows the entrant to gain more consumers at a high price as well. Of course, this latter effect makes entry more likely.

A recent paper that nicely illustrates these issues is Ellison and Ellison (2011). They look at the advertising and pricing behavior of pharmaceutical companies in the case of sixty-four drugs about to lose their patents over the years 1986–92. They first do a simple regression to determine which markets are most vulnerable to entry. For this purpose, they code each market as to whether or not there was any generic entry within three years after the expiration of the incumbent's patent. This procedure creates a 1, 0 variable for each market called Entry, where the variable is 1 if there was entry and 0 if there was not. Ellison and Ellison (2011) then try to explain this entry variable with an equation that includes three right-hand-side variables that should be related to entry. These are: Rev_i, the average annual revenue earned by the incumbent over the three years prior to patent expiration; Hosp_i, the fraction of revenues from the drug due to hospital sales in the year prior to patent expiration; and Chronic/Acute_i, which takes on the value 0 if the drug treats an acute condition but 1 if it treats a chronic condition. Their estimated equation then is:

$$\text{Entry}_i = \text{constant} + \beta_1 \text{Rev}_i + \beta_2 \text{Hosp}_i + \beta_3 \text{Chronic/Acute}_i + \varepsilon_i \tag{13.3}$$

where ε_i represents random factors that may affect entry in the ith market.

Because the dependent variable is not continuous but instead either 1 or 0, equation (13.3) cannot be efficiently estimated by ordinary least squares (OLS) regression. The linear feature of OLS means that it is quite likely that for plausible values of the independent variables the OLS estimates of the β_k coefficients will predict a value for entry outside the [0,1] interval.

Instead, Ellison and Ellison (2011) use an alternative regression procedure called Probit. This procedure effectively transforms the data so that for any value of the right-hand-side variables, the coefficient estimates give rise to a value for Entry_i that lies between 0 and 1. This predicted value is then a measure of the probability of entry given the market features.

In turn, this allows them to classify each of their sixty-four markets as one of three types: 1) low probability of entry; 2) intermediate probability of entry; and 3) high probability of entry.

Ellison and Ellison (2011) next consider the strategic use of advertising to deter entry in these markets. They start by noting that in these cases advertising by one firm has considerable spillover to the products of another. In particular, advertising by an incumbent calls attention to the specific functions of the drug, its potential benefits, its proper use, and so on, in a way that is likely to inform consumers of the benefit of later generic rivals. This is particularly the case with drugs because doctors are smart enough to realize that the active ingredients in branded medications and generics are chemically identical. It is even more the case in those states in which pharmacies are required by law to fill a prescription with a cheaper generic medication if one is available and the doctor has not explicitly forbidden it. In other words, Ellison and Ellison (2011) assume that advertising by an incumbent today will *help* tomorrow's generic entrant. Hence, if incumbents wish to deter entry, they should *reduce* advertising in the period prior to the expected emergence of a rival. Note how this implies a further complication in evaluating the evidence on entry deterrence. The other strategies we considered, e.g., capacity expansion and price-cutting, are actions that are expensive for the firm. By reducing advertising, however, the firm also lowers its expense.

Of course, whether or not incumbents will wish to deter entry will depend in part on how likely entry is. A key insight of the Ellison and Ellison (2011) paper is that the relationship between the probability of entry and strategic deterrence efforts is likely to be nonmonotonic. This is because entry deterrence is probably not worth the cost either in markets where entry is highly probable or in ones where it is very unlikely. In the first case, no amount of deterrence is likely to prevent entry. In the second case, no deterrence is really necessary. Thus, Ellison and Ellison (2011) predict that deterrence efforts will first rise (relative to what they would otherwise be) as the probability of entry rises from a low value to an intermediate one, and then fall, as the probability of entry rises still further to a high value. In terms of advertising, this means that incumbents will *lower* their advertising in those markets that their Probit regression results characterize as having an intermediate probability of entry but exhibit no advertising response to the threat of entry in either low or high probability of entry markets. Again, this is because Ellison and Ellison (2011) assume that advertising by the incumbent also has strong benefits for the generic entrant. Reducing advertising prior to the period of potential entry can then make that entry less likely. To some extent, this is precisely what they find.

Consider so-called detail advertising. By this we mean the promotional efforts of pharmaceuticals to influence physicians' prescribing practices by visiting doctors and health care providers and making direct presentations in their offices. Ellison and Ellison (2011) look at the time trend in the value of detail advertising relative to its average in the three years prior to patent expiration for each month starting 36 months before that expiration and continuing for 12 months after by estimating the regression equation:

$$\frac{Advertising_{it}}{Average\ Advertising_i} - 1 = (\beta_1 LowEntry_i + \beta_2 IntermedEntry_i + \beta_3 HighEntry_i)Time + \varepsilon_{it} \tag{13.4}$$

Table 13.1 Detail advertising trend by category of entry probability, 64 pharmaceutical markets

Coefficient	*Estimated Value*	*Standard Error*
β_1	−0.007	0.013
β_2	−0.032	0.009
β_3	0.009	0.007

The *Time* variable is just a trend term that increases by one as one moves a month closer to expiration date. The dependent variable is the ratio of advertising in the ith market in month t relative to average monthly detail advertising in that market. LowEntry, IntermedEntry, and HighEntry are each a 1,0 dummy variable indicating what entry category market i is in. The hypothesis is that β_2 will be significantly less than either β_1 or β_2, reflecting the efforts of incumbents in these markets to reduce advertising as a means of deterring entry. The estimated results are shown in Table 13.1 above.

As you can see, the estimate of β_2 is noticeably smaller (algebraically) than either of the other two coefficients. That is, the results imply that while the incumbent's detail advertising declines by less than 1 percent per month relative to the norm in high entry markets (β_1) and actually rises a bit in low entry markets (β_3), it falls by over 3 percent per month in markets with an intermediate chance of entry. Thus, Ellison and Ellison (2011) provide some interesting evidence of strategic deterrence efforts in US pharmaceutical markets in the late 1980s.

Summary

Allegations of pricing below cost to drive out a competitor and other comparable predatory strategies have been met in the last part of the twentieth century with increasing skepticism by the courts. This reflects the Chicago School view that predation is irrational. In the language of game theory, the Chicago view is that predation is not a subgame perfect strategy and it is typically dominated by other choices. Accordingly, few charges of predatory activity have been successfully prosecuted in the last twenty years or so.

At the same time, there appear to be clear historical cases of actual predatory conduct. As a result, an important question in contemporary industrial organization theory has been whether we can construct plausible models in which predatory actions are rational. The answer turns out to be yes and numerous game theoretic models have now been developed that overturn the logic of the Chain Store Paradox.

An important common feature in many of these models is asymmetric information. Asymmetries between a lender and a firm regarding the firm's true profitability, or between an established firm and an upstart regarding the incumbent's cost can make predation a feasible and attractive strategy. Even without such uncertainty, long-term and/or tying contracts can also be used to deny rivals a market. Yet while the viability of predation in both theory and practice seems clear, the proper role of public policy remains clouded.

The principal problem is one of distinguishing aggressive pricing and other competitive strategies from ones that are truly predatory—profitable only if they succeed in driving a rival out of business. Some antitrust enforcement—especially those cases prosecuted under the Robinson-Patman Act in the first thirty-five years after it was passed—appear to have been misguided efforts to protect competitors and not competition. Both economists and the courts continue to struggle with the implementation of a workable definition of predation. Empirical work testing systematic entry deterrence has been challenged by the data requirements necessary to identify predatory behavior across a set of market data points. Nevertheless this is an active research area in empirical industrial organization, holding promise for policy makers seeking to implement and enforce antitrust laws on predatory behavior.

Problems

1. Return to the Microhard Newvel game as discussed in section 13.1. Suppose now that Newvel's fixed costs are only $80 million per period. What would be the loan contract that a bank in a competitive banking industry would accept to loan Newvel $80 million in each period? Now suppose that the worst case scenario facing Newvel worsens. Specifically there is a 50 percent chance of earning $200 million and a 50 percent chance of earning only $40 million. Fixed costs are $80 million per period. Now what would be the loan contract that a bank in a competitive banking industry would accept to loan Newvel $80 million in each period?

2. Two firms are contending for a local market. The incumbent has a cost function of: $C(q_I) = 800 + 40q_I$. The upstart entrant has a cost function given by: $C(q_E) = 1300 + 36q_E$. The industry inverse demand function is given by: $P = 100 - Q$, where Q is total industry output. Prior to the upstart's entry, the incumbent acted like a profit-maximizing, uniform pricing monopolist. What price was it setting? What profit net of fixed cost did it earn? Upon the entry of the upstart rival, the incumbent quickly dropped its price to $63. How do you think the entrant will respond to this price? Does the incumbent's price-cutting constitute predation? Why or why not?

3. Suppose a buyer is willing to pay up to $200 for one unit of some good. There is currently only one supplier of the good and its cost of supplying one unit of the good is $100. Next period, a rival supplier may appear in the market. The rival's cost of supplying the good is not known. It is assumed to be uniformly distributed on the interval [50,150]. Describe a long-term contract that the current supplier can offer the buyer that will be attractive to the buyer and that at the same time will strengthen the monopoly power of the current supplier.

4. An incumbent firm has a cost function given by: $C_I = 100 + 1.5q_I^2$. Hence, its marginal cost is given by: $MC_I = 3q_I$. A recently entered rival has the cost function: $C_E = 100 + 75q_E$. Suppose the incumbent sets a price of 74 and meets demand at that price, where market (inverse) demand is given by: $P = 100 - Q$.
   a. Does the incumbent's behavior violate the Areeda-Turner rule of selling below marginal cost?
   b. Does the incumbent's behavior violate the Areeda-Turner rule when average variable cost is used as a proxy for marginal cost? Why or why not?

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14

Price Fixing, Repeated Games, and Antitrust Policy

On December 5, 2012, the European Commission announced the fines totalling €1.5 billion ($1.92 billion) on seven firms that had participated in two related, but distinct illegal cartels. This is the largest single price-fixing fine ever imposed by the Commission and the firms involved include some of world's largest electronics firms such as LG Electronics, Philips, Samsung, Panasonic, and Toshiba.[1] Notably, in this last case, the fine imposed on Asahi/AGC was reduced by 50 percent to €113.5 million in return for that firm's cooperation with the cartel investigation and its providing information that helped expose the cartel.

The European case was related to an earlier case in the United States involving the liquid crystal displays used in flat panel TVs and computer screens. That case also involved several major electronics firms including Hitachi, Sharp, Samsung, and Toshiba. Settlements with these firms in late 2011 and early 2012 resulted in fines totaling $1.1 billion. That was before the final fine levied on Au Optronics of $500 million in September of 2012. That fine matched the largest single fine the US authorities had ever levied on any price-fixing firm.

The good news is that the above conspiracies were caught and prosecuted. The bad news is that such collusive agreements are not uncommon. Early in 2012, the United States levied fines and prison sentences on three Japanese firms operating in the US that conspired to fix the prices of key auto parts such as heater control panels. In November 2009, the European Union Competition Directorate jointly fined Akzo, Ciba, Elf Aquitaine, and seven others €173 million ($260 million at the time) for fixing the price of plastic additives. In 2007, European regulators fined five elevator manufacturers a total of €992 million (approximately $1.4 billion) for operating a cartel that controlled prices in Germany, Belgium, Luxembourg, and the Netherlands. The elevator case came just one month after another case involving gas-insulated switch-gear products in which the Commission imposed fines totaling €750 million on eleven companies for their parts in a price-fixing cartel. A few years earlier, the US Department of Justice imposed a total of more than $732 million on companies operating a cartel to control the pricing of dynamic random access memory (DRAM).

Tables 14.1 and 14.2 show that these conspiracies are not isolated events. Since 1995, the US Department of Justice has detected and successfully prosecuted thirty-eight cartels in which the final fine was $50 million or more. If we extend the list to include fines

[1] Details of the European Union cases can be obtained at http://ec.europa.eu/comm/competition/antitrust/cases/index.html.

Table 14.1 US price-fixing violations yielding a corporate fine of $50 million or more since 1995

Defendant(s) & Year	*Product(s)*	*Fine* ($Million)
Au Optronics Corporation (2012)	Liquid Crystal Display Panels	$500
F. Hoffmann-La Roche, Ltd. (1999)	Vitamins	$500
Yazaki Corporation (2012)	Automobile Parts	$470
LG Display (2009)	Liquid Crystal Display Panels	$400
Air France / KLM (2008)	Air Transportation (Cargo)	$350
Korean Air Lines Co., Ltd. (2007)	Air Transportation (Cargo/Passenger)	$300
British Airways (2007)	Air Transportation (Cargo/Passenger)	$300
Samsung Electronics & Semiconductor (2006)	Dram	$300
BASF AG (1999)	Vitamins	$225
Chi Mei Optoelectronics Corporation (2010)	Liquid Crystal Display Panels	$220
Furukawa Electric Co. Ltd. (2012)	Automotive Wire Harnesses & Like Goods	$200
Hynix Semiconductor Inc. (2005)	Dram	$185
Infineon Technologies Ag (2004)	Dram	$160
SGL Carbon Ag (1999)	Graphite Electrodes	$135
Mitsubishi Corp. (2001)	Graphite Electrodes	$134
Sharp Corporation (2009)	Liquid Crystal Display Panels	$120
Cargolux Airlines S.A. (2009)	Air Transportation (Cargo)	$119
Japan Airlines Co. Ltd (2008)	Air Transportation (Cargo)	$110
UCAR, Inc. (1998)	Graphite Electrodes	$110
Lan Cargo S.A./Aerolinhas Brasileiras S.A. (2009)	Air Transportation (Cargo)	$109
Archer Daniels Midland Co. (1996)	Lysine & Citric Acid	$100
Embraco North America (2011)	Compressors	$ 92
Elpida Memory, Inc. (2006)	Dram	$ 84
Dupont Dow Elastomers L.L.C. (2005)	Chloroprene Rubber	$ 84
Denso Corporation (2012)	Automobile Parts	$ 78
All Nippon Airways Co., Ltd. (2011)	Air Transportation (Cargo & Passenger)	$ 73
Takeda Chemical Industries, Ltd. (1999)	Vitamins	$ 72
Bayer Ag (2004)	Rubber Chemicals	$ 66
Chunghwa Picture Tubes, Ltd. (2009)	Liquid Crystal Display Panels	$ 65
Qantas Airways Limited (2008)	Air Transportation (Cargo)	$ 61
Cathay Pacific Airways Limited (2008)	Air Transportation (Cargo)	$ 60
Bilhar Establishment (2002)	Construction	$ 54
Daicel Chemical Industries, Ltd. (2000)	Sorbates	$ 53
Abb Middle East & Africa Participations Ag (2001)	Construction	$ 53
SAS Cargo Group, A/S (2008)	Air Transportation (Cargo)	$ 52
Crompton (2004)	Rubber Chemicals	$ 50
Haarmann & Reimer Corp. (1997)	Citric Acid	$ 50
Asiana Airlines Inc. (2009)	Air Transportation (Cargo & Passenger)	$ 50

Source: US Department of Justice, Antitrust Division, www.usdoj.gov/atr.

Table 14.2 Cartel cases decided by the European Commission since 1990 and associated fines in €millions

Period	*Cases*	*Total Fines*
1990—94	10	€ 344
1995—99	10	€ 271
2000—04	30	€ 3,157
2005—09	33	€ 8,430
2010—12	16	€ 5,358

of $10 million or more, the number grows to nearly 100. Table 14.2 shows that the European case is similar. Since 1990 the European Commission has imposed fines in nearly 100 cases running the total fines levied to close to €18 billion.

In short, cartels happen. There appears to be no shortage of firms that enter into collusive agreements to fix prices and avoid competition. However, forming and maintaining a cartel is not easy for two, closely related reasons. The first is that such agreements are *per se* illegal.[2] That is, there is no justification that the courts will find acceptable. Both the antitrust laws of the United States and the legal framework established in Europe's Treaty of Rome, as well as the laws of most other nations, are explicit in making any and all collusion illegal and punishable by fines and (in the United States) possible imprisonment of corporate officers.[3]

The second obstacle is that the automatic illegality of collusive agreements means that the implicit contracts among the conspiring firms cannot be legally enforced. If one of the cartel members decides to price below the cartel-agreed level or to produce more than its cartel-authorized output quota, the other members cannot sue or take other legal action to curtail the renegade firm. Hence, a cartel's success requires that it find some extra-legal means of enforcing its agreement.

In this chapter, we explore the formation of cartels. This includes determining the techniques cartels may use to maintain their agreement and the conditions under which such techniques are most likely to be successful. In addition, we also address how antitrust authorities may best detect and prevent cartels.

14.1 THE PRISONER'S DILEMMA, REPEATED GAMES, AND THE FOLK THEOREM

The central issue that a potential cartel must face is clear. There are extra profits to be earned if each firm cooperates and holds production off the market to approximate more closely the monopoly outcome. Unfortunately, the price/output choices necessary for this are not typically part of a Nash equilibrium.[4]

[2] Some regulatory agencies have power to grant antitrust immunity from *per se* illegality.

[3] If anything, the language of European Union law is even stronger in that it also treats "concerted practices" based upon a "concordance of wills" as *per se* illegal. In practice, however, the US and European policy is nearly identical.

[4] A terrific guide to the intuition underlying the cartel problem and, indeed, all of game theory is Schelling (1960).

Consider, for example the simple Bertrand model of price competition with identical products. As we know, the Nash equilibrium for that case is for both firms to set price equal to marginal cost. Obviously, they could both set the monopoly price and this would greatly enhance the profit of each. The problem though is that with, say, firm 1 setting the monopoly price, firm 2's best response in *not* to set that price but to undercut it. Alternatively, consider the Cournot model. We know from Chapter 9 that if demand is given by $P = \mathrm{A} - \mathrm{B}Q = \mathrm{A} - \mathrm{B}(q_1 + q_2)$ and each firm has a constant marginal cost of c, the monopoly output is $Q^M = (\mathrm{A} - c)/2\mathrm{B}$. Hence, to achieve the monopoly outcome each duopolist would need to produce $q_1 = q_2 = (\mathrm{A} - c)/4\mathrm{B}$. Unfortunately for these firms, we also know that the best response function for each is: $q_{\mathrm{i}} = (\mathrm{A} - c)/2\mathrm{B}\text{-}q_{\mathrm{j}}/2$ $(i, j = 1{,}2;\ i \neq j$. Hence, if one firm cooperates and produces one half of the total monopoly output, the best response of the rival is not to do the same but instead to produce three-fourths of the monopoly output, thereby driving the price below the monopoly level.[5]

We illustrate the foregoing Bertrand and Cournot cases for the specific case of a market in which demand is described by $P = 150 - Q = 150 - (q_1 + q_2)$ and in which each firm has a constant marginal cost of $c = \$30$. In each case, if the firms enter into a price-fixing agreement, they will earn maximum industry profit by agreeing to cooperate to achieve the monopoly price of \$90. At that price, market demand is 60 units which we assume is shared equally between the two firms so that each earns a profit of ${\pi_i}^M = \$1{,}800$. In the Bertrand case, cheating on the agreement by either firm is very attractive as the assumption of identical products means that only a trivial price cut is necessary for either firm to steal the entire monopoly market from its rival and so double its profits to \$3,600.

The temptation to defect from the agreement is weaker in the Cournot case but, nevertheless, very real. Here, if, say, firm 1 produces its share of the monopoly output or 30 units, firm 2's best response is to produce 45 units. With a total output of 75 units, the price falls to \$75. Hence, each firm now makes $\$75 - \$30 = \$45$ on each unit with the result that by cheating, firm 2 now earns \$2,025, a 12.5 percent increase over its profits in the joint monopoly outcome. Of course, defection by both firms is tantamount to the noncooperative

Table 14.3(a) Payoffs (\$ thousands) to cooperation (M) and defection (D) in the Bertrand duopoly game

		Strategy for Firm 2	
		Cooperate (M)	Defect (D)
Strategy for Firm 1	Cooperate (M)	(\$1.8, \$1.8)	(\$0, \$3.6)
	Defect (D)	(\$3.6, \$0)	(\$$\varepsilon$, \$$\varepsilon$)

Table 14.3(b) Payoffs (\$ thousands) to cooperation (M) and defection (D) in the Cournot duopoly game

		Strategy for Firm 2	
		Cooperate (M)	Defect (D)
Strategy for Firm 1	Cooperate (M)	(\$1.8, \$1.8)	(\$1.35, \$2.025)
	Defect (D)	(\$2.025, \$1.35)	(\$1.6, \$1.6)

[5] Throughout this and succeeding chapters, we restrict our analysis to pure strategies. The reader should be aware, however, that the analysis can be extended, with some qualifications, to include mixed strategies: see, for example, Harsanyi (1973).

Reality Checkpoint

Milking the Consumer—British Retail Dairy Prices

On September 20, 2007, Britain's Office of Fair Trading (OFT) announced that it was actively pursuing charges of price fixing for milk and cheese products at Britain's four largest supermarkets—Asda, Tesco, Morrison's (Safeway) and Sainsbury's—and four of its largest dairy firms—McLelland, Dairy Crest, The Cheese Company, and Wiseman. The charge was based on coordinated price setting during the years 2002 and 2003. Ultimately, all of the firms except Tesco agreed to pay a fine of £50 ($82 million) in August of 2011. The case is interesting for at least three reasons. First, while the collusion involved the milk retailers and their dairy suppliers of cheese and fresh liquid milk, the initial push came from the dairy farmers. Because UK dairy price supports are a European Union policy, they are expressed in Euros. As the pound strengthened against the Euro in the late 1990s and early 2000s, UK farmers found the real value of raw milk prices declining and by protests and letter campaigns, pushed for payments from the dairies. Of course, the dairies could only pay the farmers a higher price if they could charge a higher price to grocery chains which, in turn, required higher retail prices.

The second point of interest is the means by which the coordination took place. The retail supermarkets were clearly aware that they could not meet directly with each other. However, each retailer did hold regular and perfectly legal meetings with their suppliers—the dairies. Soon these meetings became the locus of indirect coordination. At a meeting of its suppliers, a retailer such as Safeway would reveal that it was willing to increase its price by a certain amount provided the other retailers did the same. The date of the increase would also be discussed. Subsequently, this information was passed on to the other grocery chains when they met with those same suppliers. The result was a set of coordinated retail price increases for milk and cheese products on the order of 10 to 20 percent. About one-third of these increases were passed on to the dairy firms. Perhaps not surprisingly though, it does not appear that any of retail and wholesale price increases ever translated into higher raw milk prices for farmers.

The third interesting feature of the case is that Arla, a large dairy firm with a six percent market share, escaped any paying any fines because it was the cartel member that disclosed the price-fixing operation to OFT. This is part of the United Kingdom's leniency program designed to induce members of a cartel to come forward before they are caught. The bulk of the fines were imposed on the retailers, roughly £10 million on Sainsbury's, Tesco, and Asda, and £6 million on Morrison's. Among the dairies, Dairy Crest was fined over £7 million, Wiseman over £3 million, and The Cheese Company and McLelland a little over £1 million each.

Source: C. Binham, "Supermarkets Fined £50 Million for Price Fixing," *Financial Times* August 11, 2011; and Office of Fair Trading, "Investigation into Certain Large Supermarkets and Dairy Processors Regarding Retail Pricing Practices for Certain Dairy Products," http://www.oft.gov.uk/shared_oft/ca-and-cartels/dairy-decision.pdf.

Nash equilibrium in both the Bertrand and the Cournot cases. Tables 14.3(a) and 14.3(b) show the payoff matrices for these two games.

In short, cartel cooperation is not "natural" despite the large potential profit that it can bring because cooperation is not a Nash equilibrium for either firm. Instead, each firm's best response is always to defect from the agreement even if the rival continues to keep to it.

These situations are in fact examples of many games in which players share possibilities for mutual gain that cannot be realized because of a conflict of interest. Such games are often referred to as "prisoners' dilemma" games because one of the earliest illustrations of this case involved dealings between a prosecutor and two suspects. (See Practice Problem 14.1.)

The prisoners' dilemma is clearly a real problem for any potential cartel. Unless there is some way to overcome this conflict, it would appear that antitrust policy need not be terribly worried about cartels because logically they should not happen. Yet as we have seen cartels do happen. The evidence is compelling that collusive agreements are not uncommon and firms do pursue cooperative strategies. The prisoners' dilemma argument cannot be the full story. There must be some way that firms can create incentives that will sustain cartel agreements among them.

14.1 **Practice Problem**

Jacoby and Myers are two attorneys suspected of mail fraud in the small principality of Zenda. In an effort to obtain a confession, Sergeant First Brigadier Morse has had the two suspects brought in and subjected to separate questioning. Each is given the following options: (1) Confess (and implicate the other), or (2) Do Not Confess. Morse indicates to each suspect that if only one suspect confesses, she will be released in return for providing evidence against the other and spend no time in jail. The one not confessing in this case will "have the book thrown at her" and do ten years. If both confess, Morse indicates that he will be a bit more lenient and each will spend six years behind bars. When asked what will happen if neither confesses, Morse responds that he will find some small charge that he knows will stick, so that, in this case, each will do at least one year.
Using Confess and Do Not Confess as the possible actions of either Jacoby or Myers, derive the payoff matrix and Nash equilibrium for the game between these prisoners of Zenda.

In the last thirty years, economists have come to understand that there is a clear way around the logic of the prisoners' dilemma. The trick is for firms to look at their strategic interaction from a more dynamic perspective than that of the static Cournot and Bertrand models. Specifically, the firms need to recognize that their interaction is likely to be repeated over time. This allows firms to base their choice in any one period on how it will affect outcomes not only in the present but in future periods as well. With this modification it becomes possible for the firms that are party to a collusive agreement to reward "good" behavior by sticking with the agreement and to punish "bad" behavior by guaranteeing a breakdown in the cartel. However, in order to understand such a strategy we need to analyze what is called a repeated game—games in which a simultaneous market interaction is repeated, perhaps for many times. By moving from one period to many, we are changing the rules of the game.

14.2 REPEATED GAMES

Refer to the game of Table 14.3(a). Collusion between the two firms to produces the monopoly output is unsustainable in that it is not a Nash equilibrium to the single period game. Now suppose that firm 2 thinks forward a bit, knowing that its interactions with firm 1 are going to occur several, perhaps many, times. Suppose further that firm 1 has indicated that it will play cooperatively so long as firm 2 does, but that once firm 2 defects, firm 1 will never cooperate again. In that case, firm 2 might calculate as follows: "If I cheat on the cartel my profits go up to $2,025 and I gain a one-off increase in profits of $225. But then the cartel falls apart, and we revert to the noncooperative, Cournot equilibrium with profits to me of $1,600 per period, so that I earn $200 less per period than if I had not cheated in the first place. Is it worth my while to cheat?"

Quite possibly, the answer is no. Depending on how firm 2 discounts future profits and how credible firm 1's punishment actually is, the short, one-period gain of $225 from defecting may be offset by the loss of $200 every period thereafter. Whether or not this is in fact the case—whether or not firm 2's cooperation is fully reasonable—remains to be seen. Nevertheless, one can see that moving from a static one-period game to a repeated game may alter a firm's thinking in a manner that dramatically raises the profitability of cooperative, cartel behavior. When the market interaction among firms extends over a number of periods, there is the real possibility that cartel members are able to retaliate against defectors. Because potential defectors will rationally anticipate such retaliation, this punishment threat is a deterrent—stopping the noncooperative behavior before it starts.

The formal description of a strategy for a repeated game is quite complicated because current and future actions are now conditional on past actions. That is, a firm's action today depends critically on what has happened in previous plays of the game. To get some idea of how rapidly the complexity grows, consider the simple Cournot game in Table 14.3(a). Suppose that this game, which we will call the stage game, is played three times in succession. At the end of the first round there are four possible outcomes, that is, four possible histories. At the end of the second round, we have sixteen possible game histories—four second-round outcomes for each of the first-round results. By the third round, sixty-four game histories are possible—and this assumes that there are only two players with two possible actions to take in each round. Because, formally speaking, a strategy must define how a player acts at each round of play depending on the precise history of the game to that point, the complexity introduced by considering repeated games is formidable.

There are, fortunately, a few mental shortcuts available to us. The critical concept in this regard is the familiar one of Nash equilibrium. It is possible to identify the Nash equilibrium or equilibria for a repeated game relatively quickly if one keeps a few key principles clearly in mind. We can best illustrate these by working through our Cournot example.

Recall that when this game is played once its only equilibrium is that both firms defect. This is referred to as the "one-shot" equilibrium. Our interest is to see what happens when the firms interact with each other over and over again. We shall show that the key factor is whether the interaction is repeated over a finite (though perhaps large) number of periods or whether it goes on forever indefinitely. In other words, we can separate repeated games into two classes: (1) those in which the number of repetitions is finite *and known to the potentially colluding firms*, and (2) those in which the number of repetitions is infinite.

14.2.1 Finitely Repeated Games

When is it reasonable to assume that the number of times that the firms interact is finite *and known to both firms*? At least three situations come to mind. First, it may be that the firms exploit an exhaustible and nonrenewable resource such as oil or natural gas with a given total supply that will definitely be exhausted beyond a certain date. Secondly, the firms might operate in a market with proprietary knowledge protected by patents. Because all patents are awarded for a finite period, say, twenty years, the date of patent expiration can mark the date at which many new entrants emerge and cooperation ceases. For example, the antipsychotic drugs, *Zyprexa* and *Seroquel*, have recently dominated the market for treatment of schizoprenia, bipolar disorder, and other severe mental illnesses. Protected by their patents from any new rivals, the makers (Eli Lilly and AstraZeneca) of these two drugs could act as duopolists and perhaps work out a tacit collusive agreement. That becomes much less likely once the patents expire and new entrants can compete away the profits of those firms.

Finally, while we conventionally equate the players in the game with firms, the truth is that it is ultimately individuals who make the output or price decisions. The same management teams can be expected to be around for only a finite number of years. When there is a major change in management at one or more of the firms the initial game will likely end and this end can often be foreseen.

It turns out that what happens in a one-shot or stage game gives us a very good clue to what is likely to happen in a repeated game when the number of repetitions is finite. After all, a one-period game is just one that is very finite. Consider a simple extension of our Cournot game from one-period to two and determine what the equilibrium will be in this limited but nonetheless repeated setting.[6] When we do this we find that the two-period repeated game will have the same noncooperative outcome in each round as the one-shot game. To see why, consider the following alternative strategy for firm 1:

First play: Cooperate

Second play: Cooperate if firm 2 cooperated in the first play, otherwise Defect.

The idea behind this strategy is clear enough. Start off on a friendly footing. If this results in cooperation in the first round, then in the second round, firm 1 promises to continue to cooperate. However, should firm 2 fail to reciprocate firm 1's initial cooperation in the first round, that "triggers" firm 1 to then take "take the gloves off" and fight back in the second round. For this reason, this sort of strategy is called a "trigger" strategy.

The problem with this strategy is that it suffers from the same basic credibility problem that afflicted many of the predatory threats that we discussed in the preceding chapters. To see why, suppose firm 2 chooses to cooperate in the first round. Now think of firm 2's position at the start of its second and last interaction with firm 1. The history of play to that point is one in which both firms adopted cooperative behavior in the first round. Further, firm 2 has a promise from firm 1 that, because firm 2 cooperated in the first round, firm 1 will continue to do so in the second. However, this promise is worthless. When firm 2 considers the payoff matrix for the last round, the firm cannot fail to note that—regardless of firm 1's promise—the dominant strategy for firm 1 in the last round is not to cooperate. This breaks firm 1's promise, but there is nothing firm 2 can subsequently do to punish firm 1 for breaking its promise. There is no third round in which to implement such punishment. Firm 2 should rationally anticipate that firm 1will adopt the noncooperative behavior in the last round.

Firm 2 has just discovered that any strategy for firm 1 that involves playing the cooperative strategy in the final round is not credible, i.e., it is not subgame perfect. The last round of the game is a subgame of the complete game, and a strategy that calls for firm 1 to cooperate in this last period cannot be part of a Nash equilibrium in that period. No matter what has transpired in the first round, firm 1 can be counted upon to adopt noncooperative

[6] Even though the game lasts for two market periods, we will keep things simple and assume that profits in the second period are not discounted. In other words, we will assume that the discount factor $R = 1$ or, equivalently, the interest rate r = 0%. See the discussion of discounting in Chapter 2.

behavior in the final period of play. Of course, the same is true when viewed from firm 1's perspective. Firm 2's best strategy in the last round is likewise not to cooperate. In short, both firms realize that the only rational outcome in the second round is the noncooperative equilibrium in which each earns a profit of $1,600.

The fact that we have identified the equilibrium in the final round may seem like only a small part of the solution that we were originally seeking—especially if the game has 10 or 100 rounds instead of just 2. However, as you may recall from the Chain-Store Paradox in Chapter 11, the outcome for the terminal round can lead directly to a solution of the entire game. Consider again our two-period repeated game. In the first round, firm 1 will now see that firm 2's best first-round strategy is not to cooperate. The only reward that firm 1 can offer to persuade firm 2 from such noncooperative action in the first round is the promise of cooperation in the future in return for firm 2 cooperating today. Yet such a promise is not credible. No matter how passionately firm 1 promises to cooperate tomorrow in return for cooperation today, firm 2 will recognize that when tomorrow actually comes, firm 1 will not cooperate. It follows that the only hope firm 1 had of dissuading firm 2 from noncooperative action in the first round is gone.

Again symmetry implies the same reasoning holds true for any hope firm 2 had of inducing cooperation from firm 1. Hence, we have identified the subgame perfect equilibrium for the entire game. Both firms adopt strategies that call for noncooperative behavior in *both* period one and period two. In other words, running the game for two periods produces outcomes identical to those observed by playing it as a one-period game.

Practice Problem 14.2

Consider our first example, but now assume that the interaction between the firms extends to three periods. What will be the outcome in the final period? What does this imply about the incentive to cooperate in period two? If both firms believe that there will be no cooperation in either period two or period three, will either cooperate in period one?

We have identified the subgame perfect equilibrium for our example when the game is played for two periods. However, as Practice Problem 14.2 illustrates, our reasoning also extends to a solution for the game whether it is played two, three, or any finite number of periods, T. In all such cases, no strategy that calls for cooperation in the final period is subgame perfect. Therefore, no such strategy can be part of the final equilibrium. In the last period, each firm always chooses not to cooperate regardless of the history of the game to that point. But this means that the same noncooperative behavior must also characterize the penultimate, or $T-1$, period. The only possible gain that might induce either firm 1 or firm 2 to cooperate in period $T-1$ is the promise of continued cooperation from its rival in the future. Because such a promise is not credible, both firms adopt noncooperative-behavior in both period $T-1$ and period T. In other words, any strategy that calls for cooperative behavior in either of the last two periods can also be ruled out as part of the final equilibrium. An immediate implication is that a three-period game must be one in which the players simply repeat the one-shot Nash equilibrium three times.

We can reiterate this logic for larger and larger values of T. The outcome will always be the same Nash equilibrium as in our first example no matter how many times it is played, so long as that number is finite and known. The one-shot Nash equilibrium is just repeated T times, with each firm taking noncooperative action in every period.

The foregoing result is by no means a special case. Rather, that analysis is an example of a general theorem first proved by Nobel Prize winner Reinhard Selten (1973):

> *Selten's Theorem*: If a game with a unique equilibrium is played finitely many times, its solution is that equilibrium played each and every time. Finitely repeated play of a unique Nash equilibrium is the Nash equilibrium of the repeated game.[7]

Introducing repetition into a game theoretic framework adds history as an element to the analysis. When players face each other over and over again, they can adopt strategies that base today's action on the behavior of their rivals in previous periods. This is what rewards and punishments are all about. What Selten's Theorem demonstrates is that history, or rewards and punishments, really do not play a role in a finitely repeated game in which the basic one-shot game has a unique Nash equilibrium.

14.2.2 Infinitely or Indefinitely Repeated Games

As noted above, there are situations in which the assumption of finite repetition makes a great deal of sense and therefore to which Selten's Theorem applies. However for many, and perhaps most, situations, firms are better regarded as having an infinite or, more precisely, an indefinite life. Google may not last forever, but nobody inside or outside this giant telecommunications firm knows of a date T periods from now at which point Google will cease to exist. Our assumption that everyone knows the final period with certainty is therefore likely to be too strong. The more likely situation is that after any given period, the players see some positive probability that the game will continue one more round. So, while firms may understand that the game will not last forever, they cannot look ahead to any particular period as the last.

Why is this important? Recall the argument that we used to show that finite repetition will not lead to cooperation in a Cournot or Bertrand game. Cooperation is not an equilibrium in the final period T, and so is not an equilibrium in $T-1$, and so in $T-2$, and so on. With infinite or indefinite repetition of the game this argument fails *because there is no known final period*. So long as the probability of continuing into another round of play is positive, there is, probabilistically speaking, reason to hope that the next round will be played cooperatively and so reason to cooperate in the present. Whether that motivation is strong enough to overcome the short-run gains of defection, or can be made so by means of some reward-and-punishment strategy will depend on certain key factors that we discuss below. We will see that once we permit the possibility that strategic interaction will continue indefinitely, the possibility of successful collusion becomes a good bit more real.

In developing the formal analysis of an indefinitely repeated game, we must first consider how a firm values a profit stream of infinite duration. The answer is simply that it will apply the discount factor R to the expected cash flow in any period. Suppose that a firm knows that its profits are going to be π in each play of the game. Suppose also that the firm knows that in each period there is a probability p that the market interaction will continue into the next period. Then starting from an initial period 0, the probability of reaching period 1 is p, the probability of reaching period 2 is p^2, of reaching period 3 is $p^3, \ldots$ of reaching period t is p^t and so on. Accordingly, the profit stream that the firm actually expects to receive in period t is $p^t\,\pi$.

[7] A formal proof can be found, for example, in Eichberger (1993).

Now apply the firm's discount factor is R. The expected present value of this profit stream is given by:

$$V(\pi) = \pi + pR\pi + (pR)^2\pi + (pR)^3\pi + \ldots + (pR)^t\pi + \ldots \tag{14.1}$$

To evaluate $V(\pi)$ we use a simple trick. Rewrite equation (14.1) as:

$$V(\pi) = \pi + pR\left(\pi + pR\pi + (pR)^2\pi + (pR)^3\pi \ \ldots + (pR)^t\pi + \ldots\right) \tag{14.2}$$

Now note that the term in brackets is just $V(\pi)$ as given by (14.1), so (14.2) can be rewritten:

$$V(\pi) = \pi + pRV(\pi)$$

Solving this for $V(\pi)$ then gives:

$$V(\pi) = \frac{\pi}{1 - pR} = \frac{\pi}{1 - \rho} \tag{14.3}$$

where $\rho = pR$ can be thought of as a "probability-adjusted" discount factor. It is the product of the discount factor reflecting the interest rate and the belief the firm holds regarding the probability that the market will continue to operate from period to period.

As suggested above, repetition allows history to play a role in strategy making. In fact, many variants of the trigger strategy that would not work in the finitely repeated game will work in the infinitely repeated one. We focus on perhaps the simplest of these in which each player promises to play the cooperative action upon which all players have agreed as long as the history of the game to that point does not reveal any defections. However, if any player should deviate from the agreement then our trigger-strategy player promises to revert to the one-shot Nash equilibrium forever.

Consider again our simple duopoly example for both the Bertrand and Cournot case.[8] Suppose that the firms formulate a price-fixing agreement that gives them both profits of π^M (one half each of the combined monopoly profit). Each firm knows that if it deviates optimally from this agreement it will earn in that period of deviation a profit of π^D. Finally, denote the noncooperative Nash equilibrium profit to each firm as π^N. Common sense and our Cournot and Bertrand examples of Table 14.3 tell us that $\pi^D > \pi^M > \pi^N$.

Now consider the following trigger strategy:

Period 0: Cooperate.

Period $t > 1$: Cooperate if both firms have cooperated in every previous period. Switch to the Nash equilibrium forever if either player has defected in any previous period.

A firm whose rival is following this strategy then faces the following choice. Continue to cooperate and earn π^M or defect from cooperative play and earn π^D for one period but only π^N in every subsequent period because that defection will trigger the rival to move to the noncooperative equilibrium permanently in that following period.

[8] Our analysis generalizes to an n-firm oligopoly as we note below.

The only way to compare the gain with the loss is in terms of present values. The present value of profits from sticking to the agreement is, using equation (14.3):

$$V^C = \pi^M + \rho\pi^M + \rho^2\pi^M + \ldots = \frac{\pi^M}{1-\rho} \tag{14.4}$$

In contrast, the present value of firm 2's profits if it deviates is:

$$\begin{aligned} V^D &= \pi^D + \rho\pi^N + \rho^2\pi^N + \rho^3\pi^N + \ldots \\ &= \pi^D + \rho[\pi^N + \rho\pi^N + \rho^2\pi^N + \ldots] = \pi^D + \frac{\rho\pi^N}{1-\rho} \end{aligned} \tag{14.5}$$

Cheating on the cartel is not profitable, and so the cartel is *self-sustaining* provided that $V^C > V^D$, which requires that:

$$\frac{\pi^M}{1-\rho} > \pi^D + \frac{\rho\pi^N}{1-\rho} \tag{14.6}$$

Multiplying both sides by $(1-\rho)$ and simplifying gives:

$$V^C > V^D \Rightarrow \pi^M > (1-\rho)\pi^D + \rho\pi^N \Rightarrow \rho(\pi^D - \pi^N) > \pi^D - \pi^M$$

In other words, the critical value of ρ above which defection on the cartel does not pay leading firms to voluntarily stick by the cartel agreement is:

$$\rho > \rho^* = \frac{\pi^D - \pi^M}{\pi^D - \pi^N} \tag{14.7}$$

Equation (14.7) has a simple underlying intuition. Cheating on the cartel yields an immediate, one period gain of $\pi^D - \pi^M$. However, starting the next period and continuing through every period thereafter, the punishment for cheating is a loss of profit of $\pi^M - \pi^N$. The present value of that loss starting next period is $(\pi^M - \pi^N)/(1-\rho)$. Its present value as of today when the profit from cheating is realized is $\rho\,(\pi^M - \pi^N)/(1-\rho)$. Cheating will be deterred if the gain is less than the cost when both are measured in present value terms, i.e., if $\pi^D - \pi^M < \rho\,(\pi^M - \pi^N)/(1-\rho)$. It is easy to show that this condition is identical to that in equation (14.7). Because $\pi^D > \pi^M > \pi^N$ it follows that $\rho^* < 1$. Hence, *there is always a probability-adjusted discount factor above which a cartel is self-sustaining*.

Consider our two examples in Table 14.3. In the Bertrand case $\pi^D = 3{,}600$, $\pi^M = 1{,}800$, and $\pi^N = 0$. The critical probability adjusted discount factor above which our Bertrand duopolists can sustain their cartel is $\rho^*_B = 0.5$. In the Cournot case we have $\pi^D = 2{,}025$, $\pi^M = 1{,}800$, and $\pi^N = 1{,}600$. Substituting into (14.7) the critical probability adjusted discount factor above which our Cournot duopolists can sustain their cartel is $\rho^*_C = 0.529$. Practice Problem 14.3 below asks you to prove that these critical discount factors hold for *any* Cournot or Bertrand duopoly with linear demand and constant, equal marginal costs.

Suppose that both firms playing the Cournot game believe that their interaction will always be repeated with certainty, so that $p = 1$. Then the critical probability adjusted discount factor ρ^*_C corresponds to a pure discount factor of $R = 0.529$. That is, if $p = 1$, neither firm will deviate so long as the firm's interestrate r does not exceed 89 percent. Now suppose instead that both firms perceive only a 60 percent probability that their interaction lasts from one period to the next, i.e., $p = 0.6$. Now the cartel agreement is self-sustaining only when the pure discount factor $R > 0.529/0.6 = 0.882$. That is, successful collusion now requires that the interest rate r does not exceed 143.4 percent, which is a less restrictive requirement. This example points to a general result. An indefinitely lived cartel is more sustainable the greater is the probability that the firms will continue to interact and the lower is the interest rate.

14.3

Practice Problem

Assume a duopoly and let demand be given by $P = A - bQ$. In addition, let both firms have the same marginal cost c. Show that:

a. If the firms compete in quantities, the probability adjusted discount factor must satisfy $\rho_C^* \geq 0.529$ for collusion to be sustained; and
b. If the firms compete in prices, the probability adjusted discount factor must satisfy $\rho_B^* \geq= 0.5$ for collusion to be sustained.

14.3 THE FOLK THEOREM AND FACTORS THAT FACILITATE COLLUSION

Our analysis easily extends to cases where the number of firms is more than two. All we need do is to identify the three firm-level profits $\pi^D > \pi^M > \pi^N$ for each firm. Substituting these values into equation (14.7) then yields the critical probability-adjusted discount factor for each firm.

14.3.1 The Folk Theorem

Yet despite its general application, the success of the trigger strategy discussed above is far from guaranteed. To begin with, any trigger strategy is rooted in the assumption that cheating on the cartel agreement is detected quickly and that punishment is swift. If instead, detection and punishment of cheaters takes time then sustaining the cartel becomes more difficult because it allows the defecting firm to enjoy the gains for more periods and this raises the incentive to defect.

A further and related issue is that the trigger strategy employed above is potentially too harsh and unforgiving for a world of uncertainty and miscommunication. For example, suppose that market demand fluctuates within some known bounds, as shown in Figure 14.1, and that the cartel has agreed to set a price P^C or has agreed to production quotas that lead to that market price. In this setting, a cartel firm that observes a decline in its sales cannot tell whether this reduction is due to cheating by one of its partners or to an unanticipated reduction in demand. Yet under the simple trigger strategies we have been discussing, the firm is required quickly and permanently to move to the retaliatory behavior. Clearly, this will lead to some regret if the firm later discovers that its partners were innocent and that it has needlessly unleashed a damaging price war.[9]

In general, these obstacles to the use of a trigger strategy are important but they can in principle be overcome. Even if detection and punishment is not swift, it can still be effective

[9] Two different views of oligopolistic behavior with uncertain demand that makes detection difficult may be found in Green and Porter (1984) and Rotemberg and Saloner (1986).

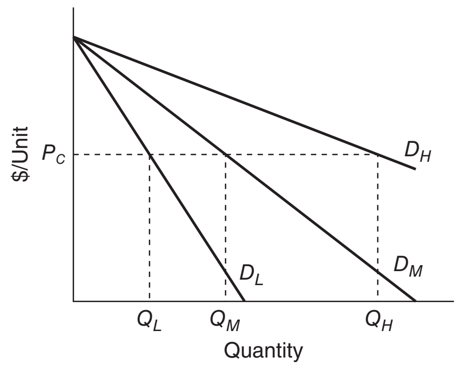

Figure 14.1 Cartel maintenance with uncertain demand
If demand is uncertain and varies between D_L and D_H with a mean of D_M, cartel members will not be able to tell whether a variation in their output is the result of normal variation in the market or cheating by other cartel members.

if the probabilistic discount factor is sufficiently large, i.e., if firms place a sufficiently large weight on the future monopoly profits that cooperation makes possible. Likewise, the issue of uncertainty can be met by adopting a modified trigger strategy. For instance, the firm might only take retaliatory action if sales or price fall outside some agreed range, i.e., the firm refrains from retaliation against minor infractions. A different modification would impose punishment swiftly after any deviation, including a minor one, is observed but limit the period of punishment to a finite period of time. Thus, we can envision a trigger strategy of the form "I will switch to the Nash equilibrium for $\tau \geq 1$ periods if you deviate from our agreement but will then revert to our agreed cooperative strategies." This approach may mistakenly punish innocent cartel members but, by limiting the period of such punishment, it permits reestablishment of the cartel at a later date.

The point is that in an infinitely repeated game there are many trigger strategies that allow a cartel agreement to be sustained. Indeed, in some ways, there are almost too many. This point is made clear by what is known as the *Folk Theorem* for infinitely repeated games (Friedman 1971):[10]

> *Folk Theorem*: Suppose that an infinitely repeated game has a set of payoffs that exceed the one-shot Nash equilibrium payoffs for each and every firm. Then any set of feasible payoffs that are preferred by all firms to the Nash equilibrium payoffs can be supported as subgame perfect equilibria for the repeated game for some discount rate sufficiently close to unity.

We can illustrate the Folk Theorem using our Cournot example. If the two firms collude to maximize their joint profits, they share aggregate profits of $3,600. If they act noncooperatively they each earn $1,600. The Folk Theorem says that any cartel agreement in which each firm earns more than $1,600 and in which total profit does not exceed $3,600 can, at least in principle, be sustained as a subgame perfect equilibrium of the infinitely repeated game. The shaded region of Figure 14.2 shows the range of profits for this example that can be earned by each firm in a sustainable cartel.

[10] The term "Folk Theorem" derives from the fact that this theorem was part of the "folklore" or oral tradition in game theory for years before Friedman wrote down a formal proof.

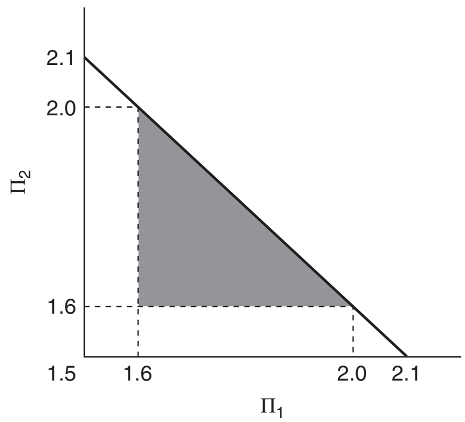

Figure 14.2 The Folk Theorem
Any distribution of profits in the shaded area can be supported by a trigger strategy for some discount factor sufficiently close to unity.

A qualifying note should be added here. The Folk Theorem does not say that firms can always achieve a total industry profit equal to that earned by a monopoly. It simply says that firms can do better than the noncooperative, Cournot–Nash or Bertrand-Nash equilibrium. The reason that exact duplication of monopoly may not be possible is that the monopoly outcome always results in the highest possible price relative to marginal cost. At such a high price, any cartel member can earn substantial short-term profit with even a small deviation from the cartel agreement. Consequently, duplicating the monopoly outcome gives members a tremendous incentive to cheat unless the probability adjusted discount factor is fairly large. Yet the incentive to deviate and break the monopoly agreement does not mean that no cartel can be sustained. Firms can still earn profits higher than the noncooperative equilibrium by means of a sustainable cartel agreement, even if they cannot earn the highest possible profits that the industry could yield. This is what the Folk Theorem says.

14.3.2 Factors Facilitating Collusion

In sum, the Folk Theorem tells us that some collusion is always a possiblility subject to two qualifications. First, the probabilistic discount factor must be sufficiently close to unity. Second, while collusion may be possible, the profit resulting from it may not be very large relative to the noncooperative outcome. It is natural then to ask under what conditions these qualifications will be important. That is, what factors make successful and profitable collusion likely?

While a complete list of all the factors that make successful collusion more likely would be very long, we concentrate here on seven factors that are particularly important. These are 1) high concentration/small number of firms; 2) barriers to entry; 3) frequent and regular orders; 4) rapid market growth; 5) technology and cost similarities; 6) product homgeneity; and 7) multimarket contact. We discuss each of these in turn.

Concentated Markets/Small Number of Firms

We are more likely to find collusion in more concentrated markets for at least two reasons. First, increased concentration typically reduces the critical probability-adjusted discount