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Collusion: Detection and Public Policy

The formation and sustained operation of cartels by means of repeated interaction among colluding firms is not only a theoretical possibility but a real phenomenon. Illegal cartels continue to emerge in practice even though explicit price fixing is illegal in the U.S., the European Union, and many other developed countries. If the price-increasing effects of these cartels were relatively small, their persistence might not warrant much concern. However, the evidence is clear that cartels raise prices by a substantial amount. For example, Froeb, Koyak, and Werden (1993) found that a price-rigging scheme involved in supplying frozen fish to the U.S. military raised prices by 23 to 30 percent. Connor (2001) found that the lysine cartel raised the market price by 17 percent, while Morse and Hyde (2000) argue the effect was a twice-as-high 34 percent. In the most exhaustive and complete review of the evidence that we have seen, Connor and Lande (2005) find that the median cartel price effect over all time periods and across all cartel types is 22 percent. They estimate that this effect is 18 percent for domestic cartels and 32 percent for international cartels.[1]

The twin facts of continued cartel formation and the consequent impact of substantially higher prices imply a clear need for an active antitrust authority charged with finding and prosecuting cartels. In a recent statement, Thomas Barnett, Assistant Attorney General of the U.S. Antitrust Division stated[2]: “The detection, prosecution and deterrence of cartel offences—such as price fixing, bid rigging and market allocation—continue to be the highest priority of the Antitrust Division.” The same concern with the detection and prosecution of cartels can be found in Europe. Since Neelie Kroes was appointed European Union competition commissioner in 2004 she has adopted a “zero tolerance” approach to cartels and has been instrumental in markedly increasing the fines that have been imposed on cartel members.

Moreover, in recent years, the antitrust authorities’ detection efforts have been quite successful. In fiscal year 2006 the U.S. Antitrust Division secured over $473 million in fines

[1] One of the few contrary studies is Sproul (1993) who finds that industry prices typically rise slightly *after* an indictment, which he interprets as evidence that cartels work to keep costs low. However, apart from notable data problems, Sproul’s (1993) analysis suffers from the difficulty that indictments only come after a long investigation. If, as many suspect, the investigation itself triggers a breakdown in the cartel, then prices will fall to competitive levels long before the indictment. What happens at that date then gives little guidance as to the actual cartel price effect.

[2] The full text of the statement can be viewed at http://www.usdoj.gov/atr/public/testimony/221777.htm.

(one of the highest totals ever) and imposed 5,383 jail days on executives found guilty of active participation in these cartels. By early March of fiscal year 2007, 18 individuals had been sentenced to a total of 12,890 days in jail. In Europe, the Commission secured cartel fines of €1.85 billion (nearly $2.5 billion) in 2006 and by the end of March 2007 had secured fines of an additional €1.74 billion ($2.3 billion). There are further cases in the pipeline in both the U.S. and in Europe (some of them involving companies thought to be members of international cartels operating in both regions) making it likely that 2007 will be another record-breaking year.

Given that enforcement of the laws against price-fixing is important, the immediate question becomes how the authorities should allocate their scarce resources (time and money) in detecting cartels. Without detailed information on the costs facing each firm and on industry demand, the authorities must develop a sense of where such illegal behavior is most likely to occur, and then police those areas more heavily. In this respect, being a good antitrust economist is like being a good detective. One has to look for clues about which firms have the motive, the means, and the opportunity to commit the crime.

Of course, identifying likely cartel behavior is not enough in itself. The real trick is uncovering evidence that will satisfy the courts. It is here that the power of recent leniency programs is revealed. While these programs may make cartel formation somewhat more likely, their primary impact is to make cartel detection much easier by encouraging finking by cartel members once they suspect an investigation is underway. It is difficult to imagine stronger evidence of the existence of a cartel than the sworn testimony of a co-conspirator.

15.1 THE CARTEL PROBLEM

In principle, collusive behavior can occur in almost any market. However, one suspects that it is more likely to occur in some markets rather than others. In order to identify the market features that facilitate collusion we first consider a central problem that colluding firms have to surmount.

Figure 15.1 presents the basic problem facing any cartel, here illustrated in the case of a duopoly. The curve $\pi_1^*\pi_2^*$ describes the *profit–possibility frontier* for two firms, 1 and 2. This frontier defines the maximum profit firm 2 can achieve for any specific profit level assigned to firm 1. The profit levels at M and other points on the frontier are achieved by an appropriate choice of output at each firm. Thus, if firm 2 is assigned zero profit (zero output), the maximum profit possible for firm 1 is π_1^*. Similarly, if firm 1 is assigned zero profit or zero output, the maximum amount of profit firm 2 can earn is π_2^*. The underlying example for this figure assumes that marginal costs are increasing for both firms but that firm 2's costs rise more rapidly than firm 1's. The problem of collusion is more interesting when costs are asymmetric between colluding firms.

There is one point on the profit frontier that generates the highest total profit for both firms. This is point M. It is identified by the fact that a straight line with slope −1, i.e., the line $\pi_m\pi_m$ is just tangent to the frontier at this point. This implies that at M a small change in the allocation of production would not affect total industry profit. Production has been allocated such that marginal cost is equal at both firms and this constant marginal cost is equal to industry marginal revenue. At M, firm 1 earns profit π_1^m, and firm 2 earns π_2^m, which is the most that it can earn given that firm 1 earns π_1^m. The sum of these two profit levels is just π_m.

Because it has a slope of −1, all points on the line $\pi_m\pi_m$ have the same *total* profit level π_m. Note that neither firm can earn this profit level by itself. That is, both π_1^* and π_2^* are

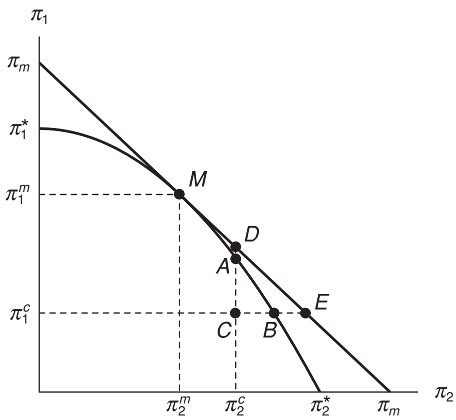

Figure 15.1 A collusive agreement between firms with different costs

The maximum joint profit that the two firms can generate is π_m, and this would give the distribution of profits at point *M*. the Cournot–Nash equlibrium is point *C*. Hence, point *M* is unattainable. However, a side payment from firm 1 to firm 2 could get the cartel somewhere on *DE*. In the absence of side payments though, the best the two firms can do is attain a point on *AB*.

less than π_m. This is because of our assumption of rising marginal cost. If firm 1 were to do all the production by itself, marginal cost would rise to a sufficiently high level that it could not earn π_m. The same is true for firm 2. The two firms need each other if they are to achieve the joint maximum at *M*.

The point *C* identifies the profit to each firm in the Cournot–Nash equilibrium. Notice that it does not lie on the curve $\pi_1^*\pi_2^*$. The Cournot outcome is a non-cooperative one. Each firm tries to maximize its own profit, not the combined profit of the industry. As a result, each ignores the fact that an increase in its own production lowers the rival's profit. Suppose, as illustrated, that *C* lies below and to the right of *M*. What this means is that firm 2 earns more profit in the Cournot–Nash equilibrium than it does producing the output it would produce at *M* and earning the profit π_2^m. This creates a real conflict in achieving the cartel goal of *M*.

This conflict can be overcome but doing so requires that the firm 2 be persuaded to act cooperatively and produce the output associated with *M*. One obvious way to do this is by means of side payments from firm 1 to firm 2. Under such an arrangement, both firms produce the outputs necessary to achieve the industry maximum at *M*. Then, to make this acceptable to firm 2, firm 1 gives up some of the large profit it makes at *M*, and pays it to firm 2. This transfer allows the firms to move along the $\pi_m\pi_m$ line and to end up somewhere on the interval *DE*.

If side payments are not possible, the best that the cartel can do is to reach some point on the arc *AB*. Total industry profit is not maximized, but at least both firm 2 and firm 1 earn a level of profit as least as great as their respective Cournot–Nash levels. However, while side payments are not necessary to achieve this outcome, some cooperation is. We know this because we know that the non-cooperative Cournot solution lies inside the frontier.

Figure 15.1 thus illustrates a central dilemma facing all oligopolists. With sufficient asymmetry across firms, achieving the point on the profit-possibility frontier that actually maximizes industry profit not only requires cooperation but also typically requires side payments in order for this to be profitable for both firms. Efficient side-payments require that the cooperating firms report their costs honestly, but each firm has a clear incentive to misrepresent their costs in order to secure a greater side-payment.

Despite these complications, firms can achieve at least some degree of cooperation. The question that remains is when such cooperation is most likely. That is, what industry characteristics are most conducive to firms achieving a cooperative outcome? This question has been the focus of considerable theoretical and empirical research.[3] The broad findings of that research now seem clear. Successful collusion is more likely when there is a sufficiently strong profit motive and when there are easily understood methods by which firms can reach and enforce a collusive agreement.

In identifying the market features that seem to be necessary for collusive behavior we will use the Bertrand model as a benchmark case. This model is very convenient for this purpose because if the firms collude they share the monopoly profit π_m, while if the cartel breaks down they earn a competitive profit of zero.

15.2 FACTORS THAT FACILITATE COLLUSION[4]

What factors make collusion easier and therefore more likely? Any factor that facilitates collusion must do one of two things. It must either reduce the critical probability-adjusted discount factor ρ^* (see Chapter) above which the cartel is potentially self-sustaining, or it must reduce the likelihood of profitable cheating by cartel members. We examine specific industry features to see whether and how they meet these criteria.

15.2.1 High Industry Concentration

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 factor ρ^*. Take our Bertrand model[5] and assume that there are n identical firms in the market. Each has profit π_m/n per period if it participates in the cartel and one-off total monopoly profit π_m if it deviates. Deviation is not profitable, therefore, if

$$\frac{\pi_m}{n}(1 + \rho + \rho^2 + \dots) = \frac{\pi_m}{n(1-\rho)} > \pi_m \Rightarrow \frac{1}{n} > 1 - \rho \Rightarrow \rho(n) > 1 - \frac{1}{n} \tag{15.1}$$

Note that if $n = 2$, equation (15.1) gives the critical probability adjusted discount factor $\rho^*(2) = 0.5$ as we found in Chapter 14. If, by contrast, $n = 4$ we have $\rho^*(4) = 0.75$ and if $n = 10$ we have $\rho^*(10) = 0.9$. The intuition is easy to see. A firm in the cartel has to share the cartel's profits with other cartel members. As a result, the returns to collusion fall as the number of cartel members increases. By contrast, the returns to deviation typically do not decrease with n. Deviation is, in other words, more profitable as industry concentration falls, i.e., as n increases.

Industry concentration affects the ability to collude for other reasons, as well. We noted in discussing Figure 15.1 that it is not always easy for duopolists to arrive at a collusive

[3] Stigler (1964) is a classic in this field.
[4] Motta (2004) provides an excellent and detailed discussion of these factors.
[5] In the exercises you are asked to conduct the same analysis for Cournot competitors.

Table 15.1 Cartels and industry concentration

Number of conspirators	2	3	4	5	6	7	8	9	10	11–15	16–20	21–25	>25	Total
Number of cases	1	7	8	4	10	4	3	5	7	5	2	–	6	62
Trade associations	–	–	1	–	4	1	–	1	3	1	1	–	6	18

	Concentration ratios				
Concentration (%)	0–25	25–50	51–75	76–100	Total
Number of cases	3	9	17	21	50

Source: Hay and Kelley (1974)

agreement if they have asymmetric costs. Matters are even more complicated when we increase the number of firms involved in the negotiations over prices and market shares. In addition, in “real life” markets with imperfect information, it may not be easy in a large-numbers cartel to detect whether and who is deviating from the agreement. Even if deviation is discovered it may be difficult for the non-deviating members to agree and implement punishment of the deviator.

Hay and Kelley (1974) provide compelling support for this proposition in their analysis of successful prosecutions of 62 cartels by the U.S. Department of Justice from 1963–1972. Table 15.1 summarizes the size distribution of these cartels.[6]

15.2.2 Significant Entry Barriers

Easy entry undermines collusion. Suppose that an entrant does not join the cartel. Ease of entry weakens the ability of the cartel to maintain its goal of higher profit. Suppose, alternatively, that the entrant joins the cartel. Then our analysis above applies: there are now more cartel members making the cartel harder to sustain. Moreover, such accommodation is likely to attract even more new entrants! Levenstein and Suslow (2006) note that “the most common cause of cartel breakdown in (their) nineteen case studies was entry” (p. 76). We can put this another way. For a cartel to succeed, it will need either to create strategic barriers to entry or to have structural ones in place.

15.2.3 Frequent and Regular Orders

An industry in which firms receive infrequent and irregularly timed orders will not be one conducive to price-fixing. The critical discount factor ρ^* is a per period discount factor (day, week, month . . .) that can be converted into an annual discount factor if we know the relevant time period. The longer the time between orders, the higher the annual discount factor. Suppose, for example, that orders are monthly and $\rho^* = 0.9$. This is equivalent to an annual discount factor of $0.9^{12} = 0.28$. If, by contrast, the period between orders is six months, then the annual discount factor is $0.9^2 = 0.81$. Simply put, with infrequent orders it takes longer to punish a firm that cheats on the cartel agreement, making cheating more attractive.

[6] Concentration ratios were available for only 50 of these cartels. We comment on the importance of trade associations below.

Reality Checkpoint
The Guild Trip

European guilds first appeared in the eleventh century as a result of growing commercial activity and urbanization. Merchants from the same city traveling to distant markets protected themselves by banding together in a caravan, called a gilde or hansa in the Germanic countries and a caritas or fraternitas in Latin-speaking ones. Caravan members had specific duties for defense if the caravan were attacked, and were also required to support each other in any legal disputes. Since the members of a hansa or fraternitas remained in touch with each other when they returned to their home city, they also began to assume rights and privileges in regard to trade within their local community—rights often supported by the authorities. This led in time to the merchant guilds monopolizing all of the industry and commerce of the city; nonguild members were only permitted to sell goods at wholesale.

Guilds based on specialized crafts replaced the earlier merchant guilds by the fourteenth century. The members of the craft guilds were all those engaged in any particular craft. They monopolized the making and selling of a particular commodity within the cities in which they were organized.

They did this in two ways: (1) by preventing goods from other cities being imported, and (2) by controlling local entry to membership in the craft guild. All those fortunate enough to be accepted as members were required to establish both uniform hours for all shops making the same commodity and uniform wages for workers in the same industry. Similarly, the number of people to be employed in each shop, the tools to be used, and the prices to be charged were all strictly regulated and enforced by close supervision. No advertising was allowed and improvements in techniques of production, which might give one artisan a cost advantage, were also prohibited. Both the merchant and craft guilds were based in the cities of their day. These were small by our standards. This size coupled with the "everyone knows everyone else's business" aspect of medieval life meant that the setting was one of frequent, repeated encounters extending over an indefinite future.

The decline of the crafts guilds came in the sixteenth century with the emergence of capitalist methods of production. This made possible the manufacture of goods on a larger scale at one point and shipping them to many others. Competition came now not from one's fellow local craftsmen but from anonymous sources further away. Policing and enforcement became impossible and the new, more efficient production methods gradually forced the craft guilds out of existence.

Source: M. Weber, *General Economic History*, Collier, New York, 1961.

That regular orders aid collusive efforts is also easily illustrated. Take our Bertrand case but suppose that in the current period ($t = 0$) a large order is received that has profit $\lambda\pi_m$, with $\lambda > 1$, while all later profits are expected to return to π_m per period. A slightly altered equation (15.1) gives the condition for the cartel to be self-sustaining in the face of this large order:

$$\frac{\pi_m}{n}(\lambda + \rho + \rho^2 + \ldots) = \frac{\pi_m}{n}\left(\lambda + \frac{\rho}{(1-\rho)}\right) > \lambda\pi_m \Rightarrow \lambda + \frac{\rho}{(1-\rho)} > \lambda n \tag{15.2}$$

Solving this for ρ gives the critical probability-adjusted discount factor

$$\rho(\lambda, n) = \frac{\lambda(n-1)}{1 + \lambda(n-1)} \tag{15.3}$$

Suppose that $n = 2$ and $\lambda = 1$ (no large orders). Then we have the familiar Bertrand condition that the probability-adjusted discount factor necessary for collusion must exceed $\rho(1, 2) = 0.5$. If, by contrast, $n = 2$ and $\lambda = 2$, then the critical discount factor necessary for collusion is $\rho > \rho(2, 2) = 2/3$. More generally, it is easy to show that $\rho(\lambda, n)$ is increasing in the parameter λ. In other words, the temptation to "steal" the profits from a one-time increase in demand can be sufficiently great to undermine the cartel. The same argument can be applied in analyzing random shocks to expected demand.[7] A positive demand shock "looks like" a large unexpected order and we have just shown that this makes the cartel harder to sustain. By contrast, a negative demand shock can provide an incentive for the cartel to stick together.

15.2.4 Rapid Market Growth

Cartels are more likely to be sustainable in growing markets and more likely to be unstable in declining markets. Once again, the intuition is simple to see. Take the case where the market is expected to grow over time. Deviation "early" in the market's growth generates profits as usual but now runs the risk of sacrificing the larger profits that the cartel will generate as the market grows. The opposite argument applies, of course, if the market is expected to decline over time. In this case, there is a stronger temptation to cheat and get out now while the gains from doing so are reasonably good.

Again we can illustrate the foregoing point using our basic Bertrand case. Suppose that the market is forecast to grow at a rate g per period. In other words, aggregate profit in period t is forecast to be $\pi_m.g^t$. For the cartel to be self-sustaining it is necessary that:

$$\frac{\pi_m}{n}(1 + g\rho + g^2\rho^2 + \ldots) = \frac{\pi_m}{n(1 - g\rho)} > \pi_m \Rightarrow \frac{1}{n} > 1 - g\rho \Rightarrow \rho(g, n) > \frac{1}{g}\left(1 - \frac{1}{n}\right) \quad (15.4)$$

Clearly, $\rho(g, n)$ is decreasing in g. We can take $g = 1$ as our base case. With the market forecast to be unchanging over time, $\rho(1, n) = 1 - 1/n$ as in equation (15.1). However, when $g < 1$, so that the market is forecast to decline, we have that $\rho(g, n) > \rho(1, n)$ and the cartel is harder to sustain. By contrast, when $g > 1$ we have $\rho(g, n) < \rho(1, n)$ and the cartel is easier to sustain.

15.2.5 Technological or Cost Symmetry

Symmetry among industry firms in terms of technology and costs is another market feature that can support cartel formation. Our analysis in section 15.1 suggests one reason why this should be the case. When two firms have different costs it will be more difficult to formulate a collusive agreement that they both find satisfactory. A firm is more able to formulate a collusive agreement with a firm that "looks like" it does rather than one that does not. In addition, detailed negotiations over prices and market shares are much more straightforward when firms are similar.

Collusion is more likely to be sustainable when the colluding firms are of roughly equal size, as they will tend to be when they have similar production capabilities. Once again, the Bertrand model provides a useful means by which this can be illustrated. Suppose that there are n firms in the cartel and that the profit share of firm i is s_i. For convenience we number

[7] Rotemberg and Saloner (1986) provide a more formal analysis.

the firms in decreasing order of their profit shares, so that $s_1 \geq s_2 \geq s_3 \geq \ldots \geq s_i \geq \ldots \geq s_n$ with, of course $s_1 + s_2 + \ldots + s_n = 1$. For firm i to be willing to remain in the cartel the condition is:

$$s_i\pi_m(1 + \rho + \rho^2 + \ldots) = \frac{s_i\pi_m}{(1 - \rho)} > \pi_m \Rightarrow s_i > 1 - \rho \Rightarrow \rho(s_i) > 1 - s_i \qquad (15.5)$$

If all the firms have equal profit shares $s_i = 1/n$ this simplifies to our "standard" Bertrand case of equation (15.1). By contrast, when profit shares are different, the firm with the lowest profit share determines the binding probability-adjusted discount factor used in equation (15.5). The smaller the share of the smallest firm, the higher that discount factor has to be for collusion to be sustainable.

15.2.6 Multi-market Contact

The fact that the same firms in an industry meet many times, i.e., the fact that the game is repeated, is perhaps the crucial element facilitating collusion. It is therefore tempting to suspect that a similar force is at work when rival firms compete in several distinct markets. That is, competing against the same set of rivals in many markets at one point in time is similar in some respect to competing against the same set of rivals in one market over several periods. Cheating in one period risks punishment and the loss of cartel profits in many subsequent periods, whereas cheating in one market could risk punishment and the loss of cartel profits in the other markets. This intuition would suggest that multi-market contact should again be a feature that facilitates collusion.

Unfortunately, the foregoing intuition is somewhat misleading because time is in fact different from space. In the multi market case a firm can cheat on all of its collusive arrangements across different markets at one point of time. However it requires the passage of time to cheat across different time periods. Nevertheless our intuition may well be correct when the colluding firms have asymmetric market shares in the different markets in which they compete.[8]

For example, suppose that two firms A and B each operate in two markets 1 and 2. Aggregate cartel profits in each market we assume to be π_m per period. The profit share for firm A in each of these markets is respectively s_{A1} and s_{A2} and we assume that $s_{A1} > 1/2$ while $s_{A2} < 1/2$. Of course we have that $s_{B1} = 1 - s_{A1} < 1/2$ and $s_{B2} = 1 - s_{A2} > 1/2$. In other words, firm A is the "large" firm in market 1 and firm B is the "large" firm in market 2. As an example, A might be a U.S. firm and B a European firm with market 1 being the U.S. and market 2 being the EU. To keep matters simple, further assume that the two firms have the same time preferences and the same discount rates. In other words, they have the same probability-adjusted discount factors.

If we treat the two markets separately, we know from our discussion in the previous section that collusion is sustainable in market 1 only if the probability-adjusted discount factor for each firm is greater than $1 - s_{B1} > 1/2$ and in market 2 only if the probability-adjusted discount factor for each firm is greater than $1 - s_{A2} > 1/2$. Now consider the two markets together. Take firm A. Firm A knows that if it deviates from the collusive agreement in either market then it will be punished in both. So if firm A is contemplating deviation it

8 See Bernheim and Whinston (1990) for a more complete analysis of this insight.

should deviate in both markets. In these circumstances, for deviation *not* to be profitable it must be that:

$$(s_{A1} + s_{A2})\pi_m(1 + \rho + \rho^2 + \ldots) = \frac{(s_{A1} + s_{A2})\pi_m}{(1 - \rho)} \geq 2\pi_m$$
$$\Rightarrow (s_{A1} + s_{A2}) > 2(1 - \rho) \Rightarrow \rho(s_{A1}, s_{A2}) \geq 1 - \frac{(s_{A1} + s_{A2})}{2} \tag{15.6}$$

The analogous result applies for firm B: $\rho(s_{B1}, s_{B2}) \geq 1 - \frac{(s_{B1} + s_{B2})}{2}$.

To see the point about multi market contact let's make it simple and suppose that firm A has profit share s in market 1 and $1 - s$ in market 2, with $s > 1/2$ to reflect asymmetric positions. Analogously firm B has profit share $1 - s$ in market 1 and s in market 2. From (15.6) the cartel between firms A and B is sustainable when they operate in both markets for any probability-adjusted discount factor greater than or equal to 1/2 (which is the standard Bertrand result again). However, the probability adjusted discount factor would have to be greater than s, which by assumption is greater than 1/2, if the firms collaborate in only one market. Multi-market contact can then support cooperation. What is necessary is first, that the colluding firms have asymmetric positions in the markets in which they jointly operate and second, that the asymmetry is reduced when all the markets in which they compete our considered. In our example, each firm had a share in excess of 1/2 in any one market. However, aggregated across both markets each firm has a share of 1/2.

15.2.7 Product Homogeneity

The empirical evidence reported in Hay and Kelley (1974) and the conventional wisdom of government authorities and the courts is that collusion is easier to sustain when the cartel members produce homogeneous or nearly homogeneous products. Again, there is an intuitive basis for this finding that stems from the complexity of the cartel agreement. First, with homogeneous products a price-fixing cartel, in principle, has to set and monitor only one price, while by contrast, collusion in pricing differentiated products requires agreeing and monitoring a different price for each product. This raises a second issue. Setting such a set of distinct prices requires that the cartel members agree on the degree to which their products are differentiated. This is a far from simple matter especially as its resolution will largely determine each firm's share of the cartel profits. Thirdly, punishment of deviation becomes more complex in a differentiated products context. Should all non-deviating firms punish a deviant or should punishment be confined to those whose products are the closest substitutes to the deviant's product? If the latter, can punishment be targeted to affect only the deviant firm or will there be spillover effects to other members of the cartel?

It should be noted, however, that there is a potential advantage to product differentiation for cartel sustainability. When the cartel members sell differentiated brands, each of which has substantial brand loyalty, then the temptation to cheat falls. If consumers exhibit considerable loyalty to their favorite brand then a deviant firm will find it hard to win much business even when it secretly cuts its price. However, the weight of the evidence suggests that cartels will be more successful—and therefore more likely—when they offer fairly homogenous products.

15.2.8 Other Factors

Several other important factors facilitate the formation and continuation of cartel agreements. Monitoring the cartel agreement is easier when prices are *observable*. This is the reason often cited for the use of *basing-point pricing*, a somewhat unusual method of pricing products that are going to be transported at some cost to the consumer. The common sense way to account for the cost of delivery is for the firm to charge a uniform price at the plant, called a mill price, and then vary the price paid by each customer depending on how much it costs to deliver the product to the customer's doorstep. This scheme is usually referred to as *free-on-board* or *fob* pricing. With basing-point pricing by contrast, one or at most, a few plant locations are picked as a basing point. All delivered prices are quoted as the mill or factory price plus the delivery cost *from the basing point*. For example, for the first twenty years or the last century, Pittsburgh was the basing point in pricing U.S.-produced steel. A consumer in Columbus, for example, paid the same price for delivered steel—the mill price plus the transportation cost *from Pittsburgh*—whether the delivery actually came from Pittsburgh or from Birmingham, Alabama.

The advantages of basing-point pricing in sustaining collusion are twofold. First, it ensures that all producers, no matter where they are located, quote the same delivered price to customers at any specific location. This is not the case with fob pricing, in which the delivered price to a given spot depends on the location of the producer. Thus, basing-point pricing considerably simplifies collusion by streamlining the price structure and making it easier to detect cheaters.

The basing-point system also weakens the incentive to cheat. Suppose that there are just two steel plants—one in Pittsburgh and one in Birmingham—and that the two firms aim to set a cooperative monopoly price. Under fob pricing, prices are set at the mill. If one firm cheats, retaliation by the other firm requires a reduction in that firm's mill price. This reduces its profit on sales to *all customers* and so imposes a considerable cost, making the threat of retaliation less credible. With basing-point pricing, however, a price cut can be made by shading the delivered price to just the area or areas in which the non-cooperative firm violated the agreement. As a result, the retaliation can be more surgically precise and, most importantly, less costly, discouraging cheating in the first place. It is little surprise that basing-point pricing schemes have now been declared illegal in the United States.

Factors that facilitate a cartel's task of monitoring its members and responding to transgressions swiftly favor collusion. Regulations that require government agencies to publish the bids they have received assist price monitoring by bid-rigging cartels. On private sector contracts, a *trade association* among the companies can help to facilitate collusive bidding behavior. The Hay and Kelley study noted above (Table 15.1) provides evidence of the importance of such trade associations in sustaining "large number" cartels.

In many consumer product markets *most-favored-customer* and *meet-the-competition clauses* can help to maintain a price-fixing agreement among firms.[9] *Most-favored-customer clauses* guarantee that if the seller offers the same product to another buyer at a lower price, the first buyer will receive a rebate equal to the difference in the two prices, whereas *meet-the-competition clauses* guarantee that a firm will match any lower price offered by another seller. It might seem surprising to think of these clauses as being anti- rather than pro-competitive but a moment's thought should indicate how they each can work to maintain cartel discipline.

[9] See Salop (1986) for more details on these competition clauses.

Reality Checkpoint

Most Favored Customer Policy Was a Bad Prescription for Medicaid

The Omnibus Budget Reconciliation Act of 1990 (OBRA 90) contained a most favored customer clause that applied to reimbursement for pharmaceuticals purchased under Medicaid. Medicaid is a very large program that accounts for nearly 15 percent of the prescription drug market sales in the U.S. The drug companies routinely offered other large buyers of drugs, such as HMOs and drug store chains, quantity discounts. However, because Medicaid did not purchase the drugs directly in bulk itself but, instead, reimbursed hospitals and pharmacies on an individual basis, it never received these discounts.

OBRA 90 included a number of steps that Congress hoped would alleviate this problem. On the one hand, it required that the drug price charged Medicaid had to be no more than 12.5 percent *less* than the average price charged all customers. Moreover, a most favored customer clause further required that if a firm charged any customer a price more than 12.5 percent below the average, that same price had to be extended to all Medicaid customers.

The theory outlined in this and the preceding chapter implies that these well-intentioned regulations may well have backfired. The most favored customer clause tends to soften price competition. If, a firm tries to cut its price in one market to gain competitive advantage there, the most favored customer clause requires that it will have to cut its price in all other markets, too. This acts as a disincentive to aggressive price competition. Indeed, the legislation also required that the Office of Inspector General monitor all firms so that there would be no secret price discounts that were not passed on to Medicaid. Of course, this meant no secret price discounts at all and, as a result, a further weakening of price competition.

Economist Fiona Scott Morton (1997) studied the impact of OBRA 90 on cardiovascular drug prices in the two years starting with January 1, 1991—the date that the regulations went into effect. She found that prices for well-known brand drugs that had been facing tough price competition from generic substitutes, actually rose by over 4 percent. This finding supports the view that most favored customer clauses, like meet the competition clauses, facilitate collusive behavior aimed at reducing price competition.

Source: Fiona Scott Morton, "The Strategic Response by Pharmaceutical Firms to the Medicaid Most Favored Customer Rules," *Rand Journal of Economics*, 28 (Summer, 1997), 269–90.

The *most-favored-customer clause* severely restricts the temptation of any seller to reduce its price since the price reduction has to be offered to all previous buyers as well. Similarly, *meet-the-competition clauses* make the process of detecting cheating particularly effective, since now the firms offering these guarantees have vast numbers of unpaid market watchers in the person of every consumer who has bought the product. At the same time, such clauses effectively bind the hands of the firms that offer them.

If meet-the-competition clauses have anticompetitive effects why are consumers lured by such guarantees? A price-matching clause is valuable to any one buyer who is assured of getting the very best deal possible. However, because that buyer then becomes implicitly a monitor of prices on behalf of the colluding firms, there is an externality to the buyer's purchase of which she may be unaware. Moreover such monitoring will lead to prices being set higher (albeit identical) for all consumers. So in fact the equilibrium outcome will be one in which all buyers are worse off.

Table 15.2 Payoff matrix for a 2 × 2 pricing game

		Strategy for firm 2	
		Price high	Price low
Strategy for firm 1	Price high	(12, 12)	(5, 14)
	Price low	(14, 5)	(6, 6)

Meet the competition clauses can also strengthen the trigger strategies that support collusive behavior among firms. To get some idea as to just how powerful this effect can be, consider a simple one-period pricing game between two firms. The payoff matrix shown in Table 15.2 describes this prisoners' dilemma game. The one-shot nature of the game leads the firms to the only Nash equilibrium in which both firms price low. Now consider what happens when we permit both firms to publish meet-the-competition guarantees that are legally and instantaneously binding.[10] These guarantees render the off-diagonal price pairs in Table 15.2 unattainable. There is no opportunity to undercut one's cartel partner when each firm has announced a meet-the-competition policy that goes into effect immediately. Because the combinations of one firm pricing low and the other firm pricing high are unattainable, neither firm has any incentive to deviate from the Price-High policy. The cartel works even in this simple one-period setting.

Stable market conditions also facilitate the detection and punishment of cheating on the cooperative agreement. When demand or production costs are uncertain and subject to random shocks it is easy to make mistakes and punish rivals wrongly suspected of cheating on the cartel. For this reason, the simple trigger strategy of punishing suspected cheating with a permanent reversion to non-cooperative play is too harsh. But a modified trigger strategy that punishes the defector only for a number of periods is not as potent a deterrent as a trigger strategy that retaliates forever. Moreover, with uncertain demand, the kinds of strategies that work to sustain collusion often do so only by establishing a market price well below that of a pure monopoly.

One way for a cartel in an unstable market to reinforce the trigger strategy is to establish a *centralized sales agency*, as in the De Beers diamond cartel, or a trade association. Either institutional arrangement can monitor and report upon both market conditions and individual firm performance. Monitoring may be further facilitated by agreements to divide the market explicitly, say by percentage of total sales or by geographic territory.

To summarize, cooperative price-fixing agreements are facilitated when an industry exhibits characteristics that make the detection and the deterrence of cheating easier. Such factors include the presence of only a few firms, selling homogeneous products on a reasonably frequent basis and under relatively stable market conditions. All of these factors have been found to be present in the prosecution of numerous recent international cartels.[11] Agreements on market division, whether by geography or sales, also make it easier to

[10] This is perfectly legal since the price-matching guarantees are offered to buyers rather than communicated to other sellers.

[11] See Connor (2001) for a detailed and very readable analysis of these cartels.

monitor the behavior of cartel members. The potential for punishment, in some cases, violence, is greatly enhanced by such features and should never be understated.[12]

15.3 AN ILLUSTRATION: COLLUSION ON THE NASDAQ EXCHANGE

Empirical evidence suggests that price-fixing arrangements are not unusual and that their impact can be large. Experience clearly shows that not all of the characteristics listed above need to be present for collusion to occur. It can occur even in conditions that seem on the surface to be quite competitive. We illustrate this point with the well-known case of collusion in the National Association of Securities Dealers Automated Quotations (NASDAQ) market.

Started in 1971, the NASDAQ was the world's first electronic stock market. Since that date it has grown rapidly and now vies with the New York Stock Exchange for position as the largest stock market in the United States. In March 2007 alone more than 33 billion shares were traded with a dollar volume of more than $822 billion.[13] NASDAQ trading is made online and for any given stock there are multiple traders.

The traders post two quotes for each stock in which they deal—an "ask" price at which they will sell the stock and a "bid" price at which they will buy the stock. By convention ask and bid prices used to be quoted in increments of eighths of a dollar. Traders make profits by quoting ask prices that are greater than bid prices but compete with each other through the ask and bid prices they quote. Market prices are determined by the lowest ask price and the highest bid price—called the *inside prices*—the difference between the lowest ask and highest bid being referred to as the *inside spread*.

Because the number of dealers trading a particular stock on the NASDAQ market can be large (sometimes as many as 60) and because entry is relatively easy, this market would seem to be pretty close to satisfying the competitive market ideal. However, other conditions favorable to cooperation are present. Play is repeated frequently and on a regular basis. The traded items (shares) are basically homogenous. Firms have very similar costs and technical abilities. Are these conditions enough to overcome the procompetitive effects of low concentration and relatively easy entry?

The work of two economists, Christie and Schultz, suggests that the answer to that question is, yes. They found that in the 1990s NASDAQ was not the competitive market it seemed.[14] The evidence came to light when Christie and Schultz constructed a matched sample of securities on the NASDAQ and on the NYSE/AMEX exchanges and compared the distribution of inside spreads. Figure 15.2 reports their results. They concluded that a much higher proportion of NASDAQ stocks had inside spreads of even eighths—2/8 or 4/8—than did similar stocks on NYSE/AMEX.

You might wonder why this should matter. After all, what is an eighth of a dollar between friends? However, given a share volume of around 1.5 billion shares per day, an additional spread of 1/8 is equivalent to additional profits of $187.5 million *per day*, a gift that most friends would be delighted to receive. Christie and Schultz suggested that collusion among NASDAQ dealers could explain the higher proportion of even eighths. The argument goes

[12] A number of cartels in New York City have used violence to enforce their market power.
[13] For further details visit the NASDAQ website at http://www.nasdaq.com.
[14] "Why do NASDAQ market makers avoid odd-eighth quotes?" *Journal of Finance*, December, 1994, pp. 1813–49.

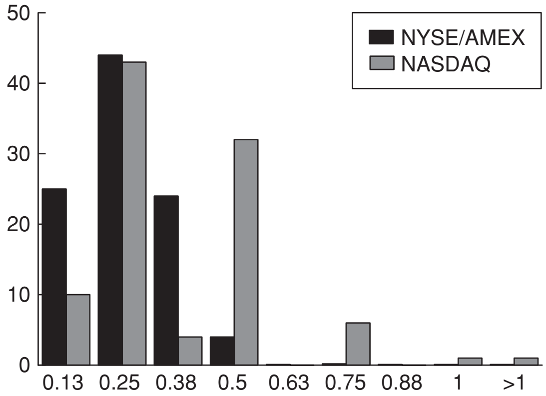

Figure 15.2 The distribution of inside spreads on NYSE/AMEX and NASDAQ
Source: Christie, W. G. and P. Schultz, "Why Do NASDAQ Market Makers Avoid Odd Eighth Quotes?" *Journal of Finance*, 49 (December, 1994): 1813–49

Reality Checkpoint

"I Am the Broker, You Are the Brokee!"

Once upon a time, two economists named Paul Schultz (of Ohio State) and William Christie (of Vanderbilt) were talking about stock prices for trades in the over-the-counter market quoted by the National Association of Securities Dealers Automated Quotation (NASDAQ) system. As described in the text, this is a computerized market in which dealers list the prices at which they will buy (the "bid" price) and sell (the "ask" price) various stocks. The difference between the bid and ask prices is the "spread," and it is a major source of dealer profits. Over time, the two economists noticed something odd. The spread was rarely less than 75 cents and always expressed as a multiplier of 25 cents, even though stock themselves are priced in odd eighths (e.g., 20 and 3/8, or 24 and 5/8). The two economists subsequently published a research paper suggesting that NASDAQ prices could only come about as a result of a price-fixing agreement.

The paper caused an immediate stir and, ultimately, led to an investigation by the antitrust division of the Justice Department. Some time later, the Justice Department filed a civil complaint against two dozen securities dealers. The complaint documented the earlier findings of Schultz and Christie. It also showed that cheating was a potential problem that the dealers dealt with by harassment and verbal assault of the culprit. For example, consider this recorded conversation of one dealer complaining to a second dealer that the latter employed a trader who was not maintaining a spread divisible by 25.

First trader: "He's trading it at one-eighths and embarrassing your firm."
Second trader: "I understand."
First trader: "You know, I would tell him to straighten up his act, stop being a (expletive deleted) moron!"

The agreement did not require the two dozen dealers involved to admit guilt or pay a fine. But it did require the dealers to cease and desist the practice and to tape randomly 3.5 percent of all trader conversations to ensure compliance.

Source: D. Lohse and A. Raghavan, "Will NASDAQ Accord Lead to Better Prices," *Wall Street Journal*, July 18, 1996, p. C1.

as follows. Essentially the NASDAQ dealers are engaged in an infinitely repeated game. When the dealers collude in their bid and ask prices then under certain conditions a dealer will earn more profit by sticking to the collusive agreement than she would earn if she defected from the agreement and undercut the other traders' inside spreads.

Let's investigate under what conditions collusion is possible. Suppose that there are N dealers in a particular stock?[15] Dealer i quotes an ask price of a_i and a bid price of b_i, both measured by convention in eighths of a dollar. The inside ask is defined as $a = \min_i a_i$, the lowest ask price, and the inside bid is defined as $b = \max_i b_i$, the highest bid price. The inside spread is, of course, $a - b$. The demand for shares of this stock by members of the public who wish to purchase at price a is denoted $D(a)$ while the supply of shares by members of the public who wish to sell at price b is denoted $S(b)$. To be specific, we will assume that:

$$D(a) = 200 - 10a \tag{15.7}$$

$$S(b) = -120 + 10b \tag{15.8}$$

where, again by convention, quantities are measured in blocks of 10,000 shares.

We make two further simplifying assumptions. First, we assume that dealers set their bid and ask prices to equate expected demand with expected supply. That is, they do not buy for inventory. What this means is that dealer i quotes ask price a_i and bid price b_i such that $200 - 10a_i = -120 + 10b_i$ which implies that $b_i = 32 - a_i$. As Figure 15.3 shows, this assumption means that the only combinations of ask and bid prices that we need consider are {(20, 12), (19, 13), (18, 14), (17, 15), (16, 16)}. Secondly, we assume that any dealer who does not quote the inside spread gets no business while all market makers who quote the inside spread share the orders equally.

We define the value of this stock, v, as the price that equates public demand with public supply. You can easily confirm that, given our demand and supply functions, $v = 16$. In other words, the value of this stock is 16 (or in dollar terms $2.00) and at that price a quantity of 400,000 shares would be traded. Aggregate profit from trading in this stock is made up of

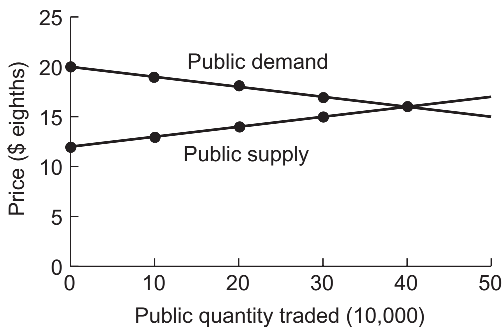

Figure 15.3 Demand and supply for a stock
The stock is traded in units of 10,000 shares and priced in increments of one-eighth of a dollar. Ask (demand) and bid (supply) prices are quoted to equate demand and supply.

[15] For a more complete, but complex, analysis see Dhutta (1999) and Dhutta and Madhavan, (1997).

Table 15.3 Profits in the NASDAQ example

Ask price a	*Bid price b = 32 − a*	*Volume of shares (10,000)*	*Aggregate profit ($000)*
20	12	0	0
19	13	10	75
18	14	20	100
17	15	30	75
16	16	40	0

Table 15.4 Payoff matrix for the NASDQ cartel game (U.S. dollars, thousands)

		Strategy for Millenial Securities (ask, bid) quotes		
		(18, 14)	*(17, 15)*	*(16, 16)*
Strategy for all other market makers (ask, bid) quotes	*(18, 14)*	$\left(\frac{100(N-1)}{N}, \frac{100}{N}\right)$	(0, 75)	(0, 0)
	(17, 15)	(75, 0)	$\left(\frac{75(N-1)}{N}, \frac{75}{N}\right)$	(0, 0)
	(16, 16)	(0, 0)	(0, 0)	(0, 0)

two components: revenues from selling at greater than v and revenues from buying at less than v. In other words,

$$\pi(a, b) = (a - v)D(a) + (v - b)S(b) \tag{15.9}$$

Given our specific demand and supply functions and the "no inventory" assumption, so that $b = 32 - a$ and $D(a) = S(b)$, this simplifies to:

$$\pi(a) = (a - b)(200 - 10a) = (2a - 32)(200 - 10a) = 20(a - 16)(20 - a) \tag{15.10}$$

Table 15.3 gives these profits at the five possible combinations of bid and ask prices.

Aggregate profit is maximized at an ask price of 18 (or $2.25) and a bid price of 14 (or $1.75) with a spread of 4 (or 50 cents) and a volume of 200,000 shares. The question is: can dealers sustain an agreement to quote these prices, or will one dealer defect and quote a lower ask and a higher bid price? Consider a particular dealer, Millennial Securities Inc. Table 15.4 gives her payoff matrix given that she quotes prices (a_m, b_m) while all other dealers quote prices (a_j, b_j).[16]

It would appear that there are two Nash equilibria to this game—(17, 15) and (16, 16). But this ignores one of the beauties of a convention to set prices in increments of eighths

[16] We can confine ourselves to the three sets of prices (18, 14), (17, 15), and (16, 16) since no trader would wish to charge (19, 13) given an agreement to charge (18, 14).

of a dollar. The strategy (16, 16) is (weakly) dominated for Millennial Securities. She never does any worse and usually does better by quoting (17, 15). So we will eliminate the (16, 16) strategy. As a result, we are left with yet another prisoners' dilemma game. If this game were to be played between these market makers only once, the collusive agreement (18, 14) could not be sustained. It is not a Nash equilibrium. Millennial Securities, among others, has the incentive to undercut the agreed prices by quoting (17, 15).

What happens if this game is repeated indefinitely? Does Millennial Securities now have the incentive to stick with the collusive prices or will she still wish to undercut them? Let p be the probability that Millennial Securities will be competing with these dealers in the next period and R be the discount factor. Millennial's discounted profit from sticking to the collusive agreement is:

$$PV^M_\infty = \frac{100}{N} + \frac{100}{N}pR + \frac{100}{N}p^2R^2 + \frac{100}{N}p^3R^3 + \ldots = \frac{100}{N(1-pR)} \tag{15.11}$$

If instead, Millennial undercuts the agreed spread she can expect rapid reaction. After all, as Christie and Schultz noted, all asks and bids are public knowledge with screen trading. So let us assume that the other dealers react to Millennial's undercutting in one period and that the collusive agreement breaks down forever. Then Millennial Securities' expected profit from cheating on the agreement is:

$$PV^D_\infty = 75 + \frac{75}{N}pR + \frac{75}{N}p^2R^2 + \frac{75}{N}p^3R^3 + \ldots = 75 + \frac{75pR}{N(1-pR)}. \tag{15.12}$$

Cheating on the collusive agreement does not pay if $PV^M_\infty > PV^D_\infty$. Simple manipulation shows that for this to be the case the probability adjusted discount factor must satisfy:

$$pR = \rho > \frac{3N-4}{3N-3} \tag{15.13}$$

At the time Christie and Schultz were doing their research, NASDAQ indicated that while there were sometimes as many as 60 dealers, there were, on average, only about 11 dealers for each stock. If $N = 11$ then necessary value of pR in equation (15.13) is $pR > 0.966$. If $N = 15$, then pR must be as high as 0.976. Since $pR = \frac{p}{1+r}$ collusion requires both a very high probability p of continued play and a very low interest rate. This, however, is where the frequency issue comes into play. The relevant time period between trades is probably not much more than an hour in any given trading day and market makers' memories carry over from day to day, if they ever go to sleep and stop trading! So the probability in any given period that a particular market maker will continue making a market in this specific stock one hour later is near unity, or $p \approx 1$. Moreover, since the relevant period is only an hour long, the interest rate that we use should also be measured on a per hour basis. A rate of 10 percent per year, for instance, implies a very small value for r per hour—less than 0.01 percent in fact. Hence, values for pR on the order of 0.99 are not at all unreasonable.

In short, the Christie and Schultz suggestion of NASDAQ dealer collusion is consistent with the conditions that economic theory predicts are necessary for such behavior. Moreover, NASDAQ's Preference Trade Rule acted very much like a "no price undercutting" guarantee. It specified that a dealer who did not post the inside spread could nevertheless receive preferenced orders provided he or she matched the best intermarket prices. Thus, not only did NASDAQ meet the basic conditions for successful collusion but also the dealers appeared to have implemented an effective enforcement mechanism. A firm like our Millennial Securities knew that deviating from the cartel price (18, 14) and pricing at (17, 15) would not win the market even for one period since all the other brokers were committed to match her.

Of course, the proof of any pudding is in the eating. The paper by Christie and Schultz served as a catalyst to an investigation of NASDAQ pricing by the Department of Justice and the Securities and Exchange Commission. The eventual outcome shows that academic research can, in fact, directly lead to the detection of a cartel.[17] The investigation produced convincing evidence of collusion and the case was settled with an agreement by NASDAQ to change its practices. Dealers were required to record at least 3.5 percent of their traders' telephone conversations with other traders and to report any violations. In addition, NASDAQ introduced a *limit order display*. This allows investors to compete directly with dealers by specifying a price and quantity at which they are willing to buy or sell a stock. If the current inside bid on a particular stock is $\$20^7/_8$ and a private investor specifies a limit order, for example, to buy 10,000 shares of this stock at \$21, then the market makers must raise their bids to \$21. The result appears to have been a considerable narrowing in spreads.

Finally, for a variety of reasons including the above analysis, the SEC required NASDAQ and other markets to change their pricing practices by moving to decimal quotations in dollars (SEC order in June, 2000) beginning "on or before September 5, 2000."[18] Interestingly enough, NASDAQ accompanied this move by a press release on the NASDAQ website citing the "increased savings potential for investors if decimal pricing leads to smaller price increments and narrower bid-ask spreads."

15.4 DETECTING COLLUSION AMONG FIRMS

In the preceding sections we have offered some guiding principles on where the authorities should watch most closely for collusive arrangements. Just watching, however, can never be enough. Even if the authorities are looking in the right place they may not detect price-fixing behavior. Some idea as to how difficult it is for the government to detect collusive behavior may be inferred from the fact that the majority of cartels that have been uncovered have only been disclosed through "finking." Sometimes the disclosure has been made by firms in the industry who have been unhappy either with the shares that they have been allocated in the cartel or because they have been excluded altogether. Sometimes it has been former employees of cartel members who have blown the whistle after losing their jobs.[19]

[17] For details see the Department of Justice press release at http://www.usdoj.gov/atr/public/press_releases/1996/343.html.

[18] To view this order go to http://www.sec.gov/rules/othern/34-42914.htm.

[19] A classic example of this is the garbage-hauling business in New York, which was controlled by a trade association between firms who carved up the city between them. Any firm attempting to enter this industry was met by threats of arson and physical violence. If a firm in the cartel took business away from another member, then the association forced the offending company to pay compensation amounting to "up to forty times the monthly pickup charge." Any firm attempting to enter the industry was met by arson and physical violence. Ex-mobsters who had been the victims of the financial penalties and violence provided some of the evidence necessary to break the cartel. (S. Raab, "To Prosecutors, Breakthrough after 5 Years of Scrutiny," *New York Times*, June 23, 1995, p. 3.)

Legally proving the existence of the cartel to the satisfaction of the courts has not been easy in many of these cases. Where successful, such prosecution has almost always been the result of the cartel members being careless. For example, they have spoken on telephones that have been tapped, or have kept permanent records of their agreements—on paper, or hard-drives on computers, and in one spectacular case inadvertently sending a copy of the agreement to a buyer along with the bid documents!

Without such evidence it is remarkably difficult for the authorities to prove, legally, the existence of a cartel. Moreover, even if uncovering a cartel is possible, there is a huge difference between detection and successful legal prosecution. The conspiring firms are entitled to their "day in court" and they have both the incentive and the ability to put up a strong defense. The cartel members have an informational advantage over any government agency, namely, the fact that they are the ones that know the nature of market demand as well as the costs of production and transportation. The best the authorities can do is to infer this information from data provided by the very same firms who are being investigated. In these circumstances, counsel for the defense can make the proof of collusion extremely difficult by making a collusive outcome appear to be competitive. This problem has been termed the *indistinguishability theorem* by Harstad and Phlips (1990).[20]

To show the indistinguishability theorem in action, we consider a case in which the European Commission ultimately rendered a verdict against ICI and Solvay, the two firms that control the European market for soda ash, which is a raw material used in glass manufacture. ICI and Solvay had operated a number of cartel agreements for many years. Solvay supplied continental Europe while ICI supplied the U.K., Ireland, and the British Commonwealth. These explicit agreements terminated in 1972, but there was no subsequent market interpenetration by the two producers. In the 1980s prices in the U.K. rose some 15 to 20 percent above those in continental Europe, which the Commission argued was greater than the transport costs across the English Channel. The Commission judged that the lack of market invasion by either firm into the other's historic regional market—especially in the face of such price differentials—was strong evidence of continued tacit collusion by the two firms.

While the Commission's judgment may appear to be sound there is a counter-argument. If each firm has the same marginal cost schedule and if each sets its price equal to marginal cost plus the cost of transportation across the Channel no cross-market penetration will ever occur. Such pricing behavior would reflect true rivalry, would lead to prices well below the collusive level, and yet there would be no market invasion of one firm by the other. Unless the regulatory agency has independent data on transportation costs, the nature of demand on each side of the Channel, and also on production costs, it cannot make a definitive case that the continued market segmentation of the market is the result of collusive action.

Similar considerations apply when defending companies who are being charged with collusion because of evidence that they changed their prices in parallel. MacLeod (1985) shows that when firms' profit functions are not known to each other then there is no systematic difference in the way that collusive and noncollusive equilibrium prices change in response to exogenous shocks. This is relevant to a 1984 judgment by the European Commission against a number of North American, Finnish, and Swedish companies who exported wood pulp to Europe for use by paper manufacturers. The Commission determined that these companies had to pay fines of between 50,000 and 500,000 ECU because they had announced and enforced parallel seasonal price changes. The judgment was thrown out on appeal in 1993 to the European

[20] For a much more detailed exposition of the indistinguishability theorem see Phlips (1995a). See also LaCasse (1995).

Court of Justice because, as the MacLeod (1985) analysis suggests, such common price responses do not necessarily imply collusion.

The situation facing government authorities is not hopeless. Sometimes a bit of good detective work can find the necessary evidence. The studies by Porter and Zona (1993) and (1999) are good illustrations of the kind of hard and thoughtful work that is necessary. Porter and Zona (1999) studied school milk procurement auctions in which a cartel was active, but in which there were also non-cartel members bidding in the auctions. They were able to show that the bidding characteristics of the cartel members were very different from those of the non-cartel members. While non-cartel members' bids increased with distance from the firm to the school district as would be expected, cartel members' bids often decreased with distance. The explanation is that the cartel members were bidding competitively in distant districts not covered by the cartel but cooperatively in proximate districts they controlled.

In their 1993 study, Porter and Zona reviewed bidding on highway paving projects on Long Island in the early 1980s. They note that since the Department of Transportation specified exactly what was to be built, the product of each firm was effectively identical. They also note that while not all firms bid on any given contract, each firm that bid knew precisely who the others were. In addition, the winning firm and its bid were publicly announced. Hence, detection of any cheating on a cartel agreement would be easy. The market outcome was concentrated. Of the 76 largest contracts, half went to one of just four firms. Finally, there were active trade associations and union groups through which the firms communicated. In short, the highway construction industry on Long Island exhibited many of the characteristics necessary for successful collusion. Perhaps it is not surprising that in 1984 one of the largest firms in this industry was convicted of price-fixing along with four other unindicted co-conspirators. The other four later faced charges in other suits. The conviction came as the result of a confession by one executive.

In their study of this market Porter and Zona (1993) ranked separately the cartel firms and the non-cartel firm by order of their unit costs. They then compared this ranking with the ranking of the submitted bids. For the non-cartel firms, the ranking of bids and costs are similar. The lower a firm's cost, the lower its bid. This is not the case for the cartel firms. For these firms, there is little relationship between their cost and bid ranks. Again, this makes intuitive sense. The choice by the cartel firms as to who among them will be the low bidder has little to do with cost: the bid is designed to generate profit. Once that firm and that bid are chosen, all the others need to do is to bid a bit higher whether their costs are a little higher or a lot.

Porter and Zona's (1993, 1999) work is insightful, but it has the advantage of working backwards. Members of the cartels had already been convicted by the time that Porter and Zona began their work. That is, they knew that a cartel was there and the only remaining question was what kind of evidence forensic economics might uncover that would further verify the collusive arrangement. While such analysis is helpful in prosecuting alleged price-fixing conspirators, the question from a policy perspective is whether this sort of work is also helpful in uncovering collusion in the first place. If the bidders on the Long Island projects had known in advance that the authorities would examine the relationship, or lack of it, between bids and firms' costs, then all they need to do to defeat the test would be to ensure that non-winning bids are ranked by costs.[21]

[21] In a related piece, Hendricks and Porter (1988) examine bids for offshore oil and gas leases. They find that firms with tracts adjacent to the tract being auctioned often lose to non-neighboring firms even though the latter are, presumably less well informed and therefore, should bid more cautiously. This suggests that neighboring firms are colluding to keep bids low.

Table 15.5 The great salt duopoly

	1980	*1981*	*1982*	*1983*	*1984*
BS profit	7,065	7,622	10,489	10,150	10,882
WP profit	7,273	7,527	6,841	6,297	6,204
BS profit per unit of capacity	8.6	9.3	12.7	12.3	13.2
WP profit per unit of capacity	6.6	6.9	6.3	5.8	5.7
Industry capacity/total UK sales	1.5	1.7	1.7	1.9	1.9

Osborne and Pitchik (1987) propose another test for detecting collusion. Recall our discussion in section 12.2.2 of the Spence (1977) and Dixit (1980) models in which a large firm invests in extra capacity as a means to discipline a new rival. Osborne and Pitchik argue that extra capacity may play a similar disciplinary role in cartels.[22] For example, we know that Bertrand price competition cannot yield the competitive outcome unless each firm has the capacity to serve the entire market. In the case of a cartel, however, acquiring such large capacity affords the firm the means to threaten the other firms with the competitive outcome if either one cheats on the collusive agreement. Osborne and Pitchik (1987) show that in this case cartel members have an incentive to acquire a larger amount of capacity.

However, it is likely that the firms choose their capacities before the collusive agreement is implemented and so the collusive agreement covers only their pricing behavior. Because the capacity choice is made non-cooperatively, it is unlikely that each will choose exactly the same amount of capacity. Accordingly, when collusion subsequently begins, the price marginal cost distinction may be the same for each firm but the profit per unit of capacity will be greater for the firm with the smaller amount of capacity. Not only will the smaller firm have a higher profit per unit of capacity but Osborne and Pitchik (1987) also show that this difference will increase as the total amount of excess capacity grows. By contrast, if there is no collusion the profits per capacity unit will be identical across firms.

Phlips (1995b) shows how this analysis can be used to examine the behavior of the two British producers of white salt, British Salt and ICI Weston Point. Many analysts suspected these two firms of collusion even after they abandoned an earlier explicit price agreement when the U.K. adopted its Restrictive Practices Act in 1956. Phlips claims that:

> Throughout the period under investigation, both British Salt (BS) and ICI Weston Point (WP) had excess capacity. BS had a given capacity of 824 kilotons, WP had a given capacity of 1095 kilotons. All I had to do was to divide the yearly profits by the capacities and to divide the sum of the capacities by total sales, to find the . . . numbers [shown in Table 15.5]. Not only was BS's profit per unit of capacity larger than WP's: it also increased relative to WP's as their joint capacity increased relative to market demand. None of these numbers is disputable . . . This beats the indistinguishability theorem: I wish more such tests were available. (Phlips, 1995b, p. 15)

15.5 CARTEL LENIENCY (AMNESTY) PROGRAMS

While our discussion in the previous section implies that the regulatory authorities face severe problems in detecting and prosecuting cartels, all is not lost. An increasing number of regulatory authorities have enacted leniency programs as a way of combating cartels. While

22 Davidson and Deneckere (1990) offer a similar analysis.

the actual programs enacted in different regions differ in their details, they typically have the form: "The first member of a cartel to provide evidence that leads to successful prosecution of the cartel receives lenient treatment. Everybody else is subject to heavy fines." Even if an investigation has been started, a lighter sentence or even total amnesty might still be offered to the first firm coming forward with evidence if this evidence proves central to successful prosecution of the cartel.[23] This new program has been wildly successful in aiding the prosecution of cartels. As the Antitrust Division of the U.S. Department of Justice has said:

> Today, the Amnesty Program is the Division's most effective generator of large cases, and it is the Department's most successful leniency program. Amnesty applications over the past year have been coming in at the rate of approximately two per month—a more than *twenty-fold increase* as compared to the rate of applications under the old Amnesty Program. Given this remarkable rate of amnesty applications, it certainly appears that the message has been communicated. (http://www.usdoj.gov/atr/public/speeches/2247.htm)

Why has granting amnesty proven so successful in breaking cartels? One reason is that such a program encourages finking by cartel members if they believe that an investigation has been started. Leniency programs put the prisoners' dilemma to work. However, as Motta and Polo (1999) and Spagnolo (2004) among others have pointed out, that explanation cannot be the whole story. For while leniency encourages confessions once an investigation is under way, it also raises the possibility of getting out of the cartel free of prosecution and thereby increases the expected net gains from starting a cartel in the first place. Indeed, the apparent evidence that more cartels are being successfully prosecuted since the advent of leniency programs might simply be the result of more cartels being formed so that with the same or even lower detection rate more conspiracies are caught!

Initiation of a leniency program involves a complicated trade-off. In order to illustrate how this trade-off might play out we use the duopoly model presented in section 14.3. Our notation is as follows. A price-fixing agreement gives a cartel member profit π^M, while optimal deviation from the agreement gives profit π^D. The non-cooperative Nash equilibrium profit to each firm is π^N. Both firms have probability-adjusted discount factors of ρ. Now consider the following game.[24] Each firm can adopt one of three strategies:

(1) (*Collude, not reveal*): Form a cartel and do not reveal evidence of the existence of the cartel if it is investigated. This is the strategy that we analyzed in section 14.3. We know from equation (14.12) that the value V^C_{NR} of expected profit is:

$$V^C_{NR} = \frac{\pi^M - asF + \dfrac{as\rho}{1-\rho}\pi^N}{1-\rho(1-as)} \tag{15.14}$$

where a is the probability that the antitrust authorities launch an investigation; s is the probability that the investigation leads to successful prosecution given that the members of the cartel do not provide evidence of the cartel's existence; and F is the maximum legal fine that can be levied on successful prosecution.

[23] For further details of the precise conditions under which amnesty might be granted see the speech by the Deputy Assistant Attorney General at http://www.usdoj.gov/atr/public/speeches/2247.htm.

[24] This game is a highly simplified version of the game presented in Motta and Polo (2003): see also Motta (2004) pp. 195ff.

(2) (*Collude, reveal*): Form a cartel but reveal its existence once an investigation has been started. Now we assume that the investigation takes one period and that the cartel firms maintain the cartel until the investigation is "nearly" complete. Each firm earns the cartel profit for one period but then both confess and the cartel collapses. To evaluate expected profit V_R^C for this strategy we consider two possibilities:

a. No investigation is initiated in period 0, which has probability $1 - a$. In this case, the cartel continues and expected profit is:

$$V_1 = (1 - a)(\pi^M + \rho V_R^C) \tag{15.15}$$

The first term in the second bracket is cartel profit in the current year, after which the "game" with the authorities resumes with expected profit V_R^C discounted by one period.

b. An investigation is initiated in period 0, which has probability a: the cartel continues until the investigation is nearing completion, at which point the firms confess and pay a reduced fine of $0 \le R < F$. The cartel then collapses. Expected profit is:

$$V_2 = a\left(\pi^M - R + \frac{\rho}{1 - \rho}\pi^N\right) \tag{15.16}$$

Summing (15.15) and (15.16) gives the expected profit from the strategy (collude, reveal) $V_R^C = V_1 + V_2$.

Solving for V_R^C gives:

$$V_R^C = \frac{\pi^M - aR + \dfrac{a\rho\pi^N}{1 - \rho}}{1 - (1 - a)\rho} \tag{15.17}$$

Equation (15.17) reveals the potential downside of a leniency program. Expected profit is decreasing in the fine R. In other words, the more generous the leniency program—the smaller is R—the more profitable is (collude, reveal) and so the more likely it is that a cartel will be formed.

(3) *Defect* on the cartel in period $t = 0$, in which case, of course, the cartel breaks down or, more accurately, is never effectively formed. We know from equation (14.5) that the value of expected profit in this case is:

$$V^D = \pi^D + \frac{\rho\pi^N}{1 - \rho} \tag{15.18}$$

We need some further assumptions to complete the analysis. If both firms defect then no cartel is ever formed and each firm has profit $V^N = \pi^N/(1 - \rho)$. If one firm defects while the other does not the defecting firm earns V^D while the non-defecting firm makes "very low" profits V^L. If one firm reveals while the other does not, the revealing firm earns V_R^C as above while the non-revealing firm earns $V_R^C - D$ where $D > 0$ can be calculated by substituting F for R in equation (15.17). This gives the payoff matrix of Table 15.6 in which Firm 1's payoffs are listed first.

Inspection of Table 15.6 reveals that it has potentially a number of possible Nash equilibria. (*Defect, defect*) is, of course, one of these. The non-cooperative Nash equilibrium to

Table 15.6 Payoff matrix with a leniency program

		Strategy for firm 2		
		Defect	*Collude, reveal*	*Collude, not reveal*
Strategy for firm 1	*Defect*	(V^N, V^N)	(V^D, V^L)	(V^D, V^L)
	Collude, reveal	(V^L, V^D)	(V^C_R, V^C_R)	$(V^C_R, V^C_R - D)$
	Collude, not reveal	(V^L, V^D)	$(V^C_R - D, V^C_R)$	(V^C_{NR}, V^C_{NR})

the one-shot game repeated over and over is always one of the potential equilibria to the repeated game. As Table 15.6 shows, however, there are also other and more interesting equilibrium possibilities. In particular:

1. (*Collude, reveal*) for both players is an equilibrium provided that $V^C_R > V^D$;
2. (*Collude, not reveal*) for both players is an equilibrium provided that $V^C_{NR} > \max\{V^C_R, V^D\}$

Indeed, an interesting feature of this game is that if $V^C_{NR} > V^R_C > V^D$, then there are actually three equilibria. These are: both defect, both play (collude, reveal) and both play (collude, not reveal). It seems reasonable to assume that if the firms are able to agree on forming a cartel, then they will also be able to agree to choose the most profitable strategy combination for the cartel, which in this case would be (collude, not reveal).

To make matters more concrete, we now illustrate the impact of the leniency program using the Bertrand example of section 14.3. Recall that in this example, we have: $\pi^M = 1{,}800$, $\pi^D = 3{,}600$ and $\pi^N = 0$. In the context of the model above, this yields:

$$V^C_R = \frac{1{,}800 - aR}{1-(1-a)\rho};\; V^C_{NR} = \frac{1{,}800 - asF}{1-(1-as)\rho};\; V^D = 3{,}600 \tag{15.19}$$

We also assume that the antitrust authority can use its scarce resources to affect three parameters in our model. These are: (1) the probability a that an investigation is initiated; (2) the probability s that the investigation is successful in identifying the cartel; and (3) R, the strength of the leniency program. The maximum penalty F paid in litigation that results in a conviction is, on the other hand, determined by the courts. We set this at $F = \$3{,}600$ or twice the per period excess cartel profit. (Recall that private antitrust lawsuits pay treble damages to successful plaintiffs.) Given that we know F and ρ we can illustrate how the parameters a and s determine the equilibrium for a given value of R. Finally, for convenience and without being too unrealistic, we set $\rho = 0.8$.

Table 15.7 gives the profits for each of the three strategies for any values of a and s, and for two values of R, namely, $R = 0$ (complete amnesty); and $R = \$600$ (one-third of the cartel profits). From Table 15.7 we have:

(1) $V^C_R > V^D$ if $a < a_{CR}(R) = 3/8$ if $R = 0$ and $= 9/29$ if $R = 600$;
(2) $V^C_{NR} > V^D$ if $a < a_{CNR}(s) = 1/6s$;
(3) $V^C_{NR} > V^C_R$ if $a < a_{ES}(R, s) = (2 - 3s)/4s$ if $R = 0$ and $(13 - 18s)/20s$ if $R = 600$.

Table 15.7 Profits for the leniency program game

	$R = 0$	$R = 600$
V_R^C	$\frac{9{,}000}{1 + 4a}$	$\frac{3{,}000(3 - a)}{1 + 4a}$
V_{NR}^C	$\frac{9{,}000(1 - 2as)}{1 + 4as}$	$\frac{9{,}000(1 - 2as)}{1 + 4as}$
V^D	3,600	3,600

The subscript *ES* in (iii) stands for "equilibrium selection" when both (Collude, reveal) and (Collude, not reveal) are Nash equilibria. Given our equilibrium selection assumption, (Collude, reveal) is the equilibrium for $a \in [a_{ES}(R, s), a_{CR}(R)]$, (Collude, not reveal) is the equilibrium for $a < \min\{a_{ES}(R, s), a_{CNR}(s)\}$ and no cartel is formed otherwise.

These outcomes are illustrated in Figure 15.4 and allow us to highlight the conflicting effects of the leniency program. Look first at Figure 15.4(a), which assumes that the leniency program offers compete amnesty or $R = 0$. If no leniency program exists a cartel

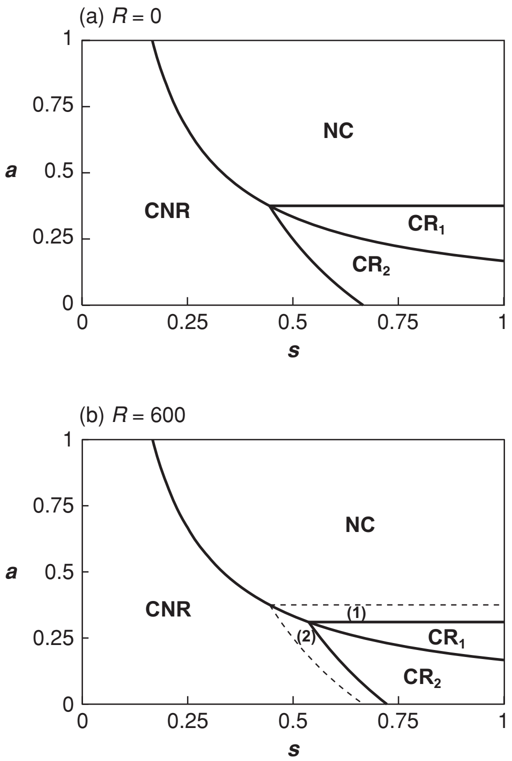

Figure 15.4 Equilibria with a leniency program

Reality Checkpoint

Leniency Program Succeeds—Only Too Well

The Competition Directorate of the European Commission introduced its leniency program in 2002 and updated the program in December 2006. The new program guidelines include the following provisions:

- Fines are up to 30 percent of the sales value affected by the cartel, multiplied by the number of years over which the cartel operated;
- Cartel members will also be fined an "entry fee" for joining the cartel, which will be between 15 and 25 percent of annual sales in the sectors affected by the cartel.
- Repeat offenders can have their fines doubled for a second offence, tripled for a third offence and so on.
- Fines can be further increased for companies that do not cooperate with the Commission's investigation and for the ring-leader in the cartel.
- Fines can be decreased if a company fully cooperates with the cartel investigation.
- Companies that "blow the whistle" on the cartel receive full immunity from punishment.

The problem is that this policy appears to be almost too successful. The lure of immunity has generated more than 200 applications since 2002. While this has led to a series of high-profile successes, it also runs the risk of overwhelming the 70 specialist investigators. Even with evidence provided by immunity applicants, cartel investigations currently take at least three years to complete. The flood of immunity applications threatens to drag this out even more. In response, the competition commissioner Neelie Kroes has floated the idea of offering "direct settlements": reduced fines in return for cooperation with the cartel investigation and the promise not to appeal the Commission's final ruling. However, this proposal faces many practical and legal obstacles so for the time being it looks as if the investigators will have to soldier on with their increased workload unless, of course, some of the rapidly growing revenues from fines are used to hire additional investigators!

Source: "Cartels Feel Pain Of Kroes Crusade," *Financial Times*, Companies International, Thursday, March 29, 2007.

will be formed only if the probability of an investigation $a < a_{CNR}(s)$ and these cartels will not reveal evidence if they are investigated. There is no incentive to do so if there is no hope of leniency.

The leniency program extends the parameter region in which cartels form. If a and s lie in region CR_1 cartels form using the strategy (collude, reveal) whereas without the leniency program no cartels form in this region. On the other hand, cartels in the region CR_2 that follow the policy (collude, not reveal) in the absence of a leniency program now switch to (collude, reveal), potentially making the antitrust authorities' detection problems somewhat easier. In other words, the leniency program encourages the creation of more cartels but also makes them easier to find and prosecute.

The same conflict arises when we compare the generous leniency program of Figure 15.4(a) with the less generous program of Figure 15.4(b), in which $R = 600$. In region (1) cartels that would form with the generous program do not form with the less generous program. On the other hand in region (2) cartels that would adopt (collude, reveal) with the generous program adopt (collude, not reveal) with the less generous program. A less generous leniency program creates fewer cartels but makes them harder to find.

15.6 EMPIRICAL APPLICATION An Experimental Investigation of Leniency Programs

The observation that many more cartels have been uncovered since the adoption of leniency programs has not yet yielded a large number of efforts to test the effect of such programs empirically. In part, this reflects the difficulty that attends the fact that the only cartel evidence we can ever have relates to cartels that have been successfully prosecuted rather than to those that successfully avoided detection. This creates a serious problem in using statistical evidence from actual data to evaluate the effectiveness of leniency programs. We have used statistical evidence and more specifically, formal regression analysis, in many other chapters in this text, and it is probably clear from these that in some real world cases, such analysis is difficult at best. In recent years economists have turned to an alternative source of economic data—namely, using individuals to conduct laboratory simulations of actual economic interactions. While such controlled experiments are contrived, when done carefully they can nonetheless offer important insight into real-world settings.

In this section we report on an experiment designed by Hinloopen and Soetevent (2006) (HS hereafter) in which they assess the impact of leniency programs on cartel formation, effectiveness and duration.[25] The experiment consists of volunteer subjects playing a repeated Bertrand game against each other. Four different treatments or settings are examined, each played by different groups of respondents. The *Benchmark* case is just the Bertrand pricing game without communication between players. *Communication* is the same game except that players are allowed to communicate before setting prices via computer screens. *Antitrust* introduces a 15 percent probability in each period that any cartel or communication that is formed is detected. Finally, *Leniency* gives cartel members the option of reporting the cartel in return for a reduced penalty.

In each treatment each subject is randomly assigned to a group of three without knowing who the other two group members are: throughout the experiment all communications between players take place through computer screens. The subjects play a repeated discrete price Bertrand game against the other players in their group. All groups play independently.

The precise play of the game is that in each period, each of the three subjects acts like a firm and sets price by choosing an integer in the range 101–110. Those members of a group who set the lowest price p receive net earnings of $\pi = (p - 100)/L$ where L is the number of group members setting the lowest price. All other group members earn nothing. In each treatment or setting, the game is played for at least 20 periods and this is known from the start. The subjects are informed that after period 19 each next period would be the last one with probability 20 percent: this is intended to attenuate end-period effects.

The one-shot equilibrium for this pricing game is for all players to set a price of 101. The indefinitely repeated equilibrium is for all players to set a price equal to 110 provided that players' are sufficiently patient (HS provide a formal proof of these results).

In each round of play, the subjects in the *Leniency* treatment have the most steps. There are seven steps as follows:[26]

[25] Jeroen Hinloopen and Adriaan R. Soetevent, "Trust and Recidivism: The Partial Success of Corporate Leniency Programs in the Laboratory," Tinbergen Institute Discussion Paper TI 2006-067/1, 2006, available at http://www.tinbergen.nl.

[26] Detailed descriptions of subject instructions are provided in the Hinloopen and Soetevent (2006) paper.

Step 1: Decide whether or not to communicate with the other group members. If all three choose to communicate move to step 2, otherwise move to step 3.

Step 2: Communicate by suggesting minimum and maximum prices. Players have one minute to reach an agreement through repeated iteration on these prices.

Step 3: Each player in the group sets a market price. This need not be the price agreed in step 2, since agreements are non-enforceable, giving players the option to defect on an agreement.

Step 4: Market price is revealed. Market price is equal to the minimum price submitted by the three group members in step 3.

Step 5: If a cartel is formed in step 1 players are given the option of reporting the cartel. Reporting costs one point. The first player to report receives full amnesty, the second a 50 percent reduction in the fine and the third no reduction. The point deduction for non-reporting group members (or the third member to report) is 10 percent of gross earnings for the relevant period.

Step 6: If no report is submitted in step 5 there is a 15 percent probability that the cartel is detected, in which case all players pay the full point deduction.

Step 7: Close of the game for this period, when players are notified of their earnings (points) for this period, whether a reporting decision was made and how many players in the group reported.

In contrast to the Leniency group, those in the Benchmark treatment are restricted to only three steps: steps 3, 4 and 7. Those in the Communication treatment have five steps omitting steps 5 and 6, while those in the Antitrust treatment have six steps, omitting step 5.

In all treatment groups, the subjects can at any time, review the entire history of their rivals' play on a scrollable screen. At the end of the experiment, the profit points accumulated by a player are converted into euros at an exchange rate of one point for €0.25.

The experiment was conducted over the period June 13–17, 2005 at the University of Amsterdam, with subjects drawn from a large pool of undergraduates across all subject fields. There were approximately 40 subjects in each treatment. This allows running that scenario with different sets of players. Remember that the players in this game are just people like you! They are not actual firms. However, they do have a monetary incentive and they do understand the rules of the game. So, their behavior should tell us something about real world cartel formation.

Table 15.8 summarizes the overall intention to form a cartel among players in each of the three settings in which formation is possible. (Recall that in the Benchmark group, no communication is allowed.) The first row shows the average fraction of players in that treatment

Table 15.8 Cartel formation

	Communication	*Antitrust*	*Leniency*
Cartel intention	78.08	64.74	62.26
Always	30.77	20.51	23.81
Never	0.00	0.00	9.52
Cartel formation	47.31	27.31	12.86

group who wanted to form a cartel in any given period. The next two rows show the fraction of players in a treatment group who either: (a) always wanted to form a cartel in every period; or (b) never wanted to form a cartel in any period. The final row shows the average number of cartels formed for each group.

On average 78 percent of those who had the opportunity to collude on price without fear of any antitrust prosecution were interested in forming a cartel. This falls to 65 percent when an antitrust authority with a 15 percent detection rate is introduced. Perhaps somewhat surprisingly, introducing a leniency program does not noticeably reduce this willingness any further.

Since unanimity is an important element in a cartel's success, the actual number of cartels formed is much less than the average fraction of players interested in forming one. In this experiment not only does the presence of an active antitrust agency cut cartel formation by 20 percentage points, but the augmentation of that agency's policy to include a leniency program reduces cartel formation by a further 15 percentage points. Thus, this initial evidence suggests that fears that leniency works to encourage cartel formation may be overstated. Moreover, with leniency there is a small group of subjects that is persistent in their unwillingness to participate in a cartel at all, which the authors interpret as the first indication that the leniency program is working to break down trust among potential cartel members.

Of course, the fact that cartel formation declines with the emergence of a leniency program does not necessarily give us a complete description of the effect of that program. It may be that even though there are fewer cartels, the ones that form are more aggressive in that they set a higher cartel price. Evidence on this point is provided in Table 15.9 and 15.10. A quick inspection of the first of these indicates, however, that there is no significant difference across treatments in the average agreed-upon price. A similarly quick inspection of Table 15.10 indicates that the average market price actually established is somewhat lower with a leniency program. There is in this experiment little evidence that the beneficial effect of a leniency program in reducing cartel formation is offset by higher prices in those instances in which cartels are actually formed. If anything, the leniency program seems to have a pro-competitive effect on prices. In addition, the average defection size—the difference between

Table 15.9 Agreed-upon prices

	Mean	*Median*	*Minimum*	*Maximum*
Communication	109.40	110	102	110
Antitrust	109.12	110	103	110
Leniency	109.60	110	105	110

Table 15.10 Average market prices

	Benchmark	*Communication*	*Antitrust*	*Leniency*
All	103.24	103.31	103.04	101.38
Cartels	—	105.43	104.82	103.39
Non-Cartels	103.24	101.40	102.38	101.08

Table 15.11 Cartel breakdown

	Fraction of cartels			*Fraction of cartel members*	
	Defection	*Detection*	*Reporting*	*Defection*	*Reporting*
Communication	0.67	—	—	0.52	—
Antitrust	0.68	0.17	—	0.50	—
Leniency	0.94	0.03	0.78	0.72	0.40

the agreed-upon price and the market price—is greatest in the Leniency treatment. It would appear that in this treatment defectors want to be more certain of capturing the entire market, a second indication that the leniency program is working to undermine trust between cartel members.

We now return to the question about the role of leniency or amnesty programs in detection of price-fixing agreements. Table 15.11 presents the HS results regarding cartel breakdowns using as a unit of analysis both cartels, themselves, and also actual cartel members. The evidence indicates that a large fraction of cartels—roughly two-thirds—suffer at least a temporary break down and as many as 94 percent of cartels break down. The HS evidence also shows that when a leniency program exists, a sizable percentage of cartel defection is accompanied by members reporting to the antitrust authorities in order to take advantage of the leniency offer. If by detection we also mean finking, this evidence suggests that leniency programs actually do enhance the discovery of illegal cartels. In turn, their findings suggest that another reason for the high rate of defection when leniency is introduced is that leniency leads cartel members to defect before they can be reported, a third indication that the leniency program undermines trust among cartel members.

HS conclude that the evidence from their experiments imply that leniency programs lower prices for three reasons. These are:

1. Cartel formation is made more difficult.
2. Defection is more likely and more frequent.
3. Defection is more severe in so far as there is a greater difference between the agreed-upon price and the undercutting price.

In effect, leniency programs undermine trust among potential cartel members.

HS also use statistical analysis to illuminate the dynamics of prices over the course of a cartel. As Sproul (1993) found in a number of real world cartel cases, HS find that their laboratory generated cartel prices tend to rise at the moment of detection. The reason for this is in the HS generated data is equally clear. Because in the basic Antitrust treatment group, there is a constant 15 percent chance of detection in any period, the cartels most likely to be caught are those that are most successful and last the greatest number of periods. However, these are precisely the ones in which the price is likely to be highest. The statistical data may show a correlation between cartel detection and high prices but this should not necessarily lead to the inference made by Sproul (1973) that cartels work to keep costs, and therefore prices down. That correlation is present in the HS simulations even though it is clear from the way the experiment is set up that the only role of cartels in this setting is to raise prices.

Summary

Collusion, both explicit and tacit is a topic of great interest and importance to both industrial economists and antitrust authorities. Uncovering and prosecuting cartels is a major policy goal. This is because the vast bulk of evidence and experience reveals not only that cartels happen but that, when they do, the effect on price is substantial—on the order of 20 or 30 percent above the price that would have prevailed in the absence of collusion. To pursue their goal of detection and successful prosecution efficiently, antitrust authorities need to use economic theory and evidence so as to focus on those markets in which cartel formation is most likely and will do the greatest harm.

Theory suggests that markets in which collusive agreements are likely to succeed are ones with just a few firms in total or at least where just a few firms account for most of the output. Such markets will also typically exhibit a low elasticity of demand, substantial barriers to new entry, relatively homogeneous products, similar cost functions across firms, and relatively stable market conditions. Virtually all cartels that have been uncovered have occurred in industries that meet these conditions.

Just knowing where to look for cartel arrangements, however, is not enough. Authorities must have the additional ability to identify collusion accurately and to prosecute it successfully. Yet obtaining compelling evidence of price-fixing is difficult, particularly since the authorities often have to rely on the very same firms it is investigating to obtain the incriminating information. This is no doubt why so many cartels have been uncovered only as a result of revelations by rivals, suppliers, employees, or customers of the firms involved. In this light, Phlips' call for the development of more tests to discriminate between collusion and non-collusion is well noted. Whether economists will be able to answer that call remains to be seen.

In the meantime, the antitrust authorities are probably doing the best they can by using leniency programs. As we have shown, however, these may not the simple panacea that some analysts hoped they would be. On the one hand they certainly make cartel detection easier since evidence provided by a cartel member attesting to the operations of the cartel is undoubtedly compelling. On the other hand the prospect of a "free walk" may reduce the costs of joining a cartel, potentially encouraging cartel formation that would otherwise not have occurred. Experimental evidence suggests however that leniency programs ultimately lead to lower prices because there is an overall adverse effect on cartel formation.

Problems

1. Explain why collusion is more likely to occur in industries with higher concentration.
2. Repeat the proofs of sections 15.2.1 and 15.2.3 for the Cournot model of Chapter 14.
3. Suppose that fence companies submit sealed bids for government contracts to put guard rail on highways. Devise a method for submitting bids that spreads the work evenly among the companies.
4. When highway departments receive bids from guardrail and other construction firms, they regularly open the sealed bid tenders and announce the identity and the bid of the winning bidder. Do you think that this practice facilitates or hinders collusion among the construction firms?
5. List the features of the NASDAQ market that facilitate collusion. What features would make collusion in this market difficult? How should this affect policy?
6. Why has the OPEC oil cartel been successful in raising prices, while the CIPEC copper cartel has not?
7. Suppose that a cartel has just been created and it includes both large and small firms, each having different average and marginal costs curves. The cartel agreement is for each member to reduce its output by 20 percent from the current level. Suppose that the current level of industry output approximates the competitive output level. Will this 20 percent reduction rule maximize the cartel's profit? Explain why or why not.
8. It has been often noted that cartel firms often maintain excessive capacity. This is true for example in the case of OPEC (especially for

Saudi Arabia). It was also true in the electric turbine conspiracy of the 1950s and, more recently, the international lysine conspiracy of the 1990s, among others. One explanation of this is that the success of the cartel inevitably leads the members to reinvest their profits in new capacity. In this view, the cartel sews the seeds of its own destruction. Based on the analysis of this chapter, can you give an alternative explanation? What implications does your explanation have for the long-run viability of the cartel?

9. Show how Figure 15.4 is affected if:
   a. the fine that is imposed is decreased to 1,800; or
   b. each firm's probability-adjusted discount factor is increased to $\rho = 0.9$. Interpret your answers.

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