

Explicit Collusion and Market Share Allocations*

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Abstract

We show that explicit cartels can implement market share allocations using a reporting framework that is considered to be legally acceptable for trade associations. This simple resolution of the market share cartel's monitoring problem provides an explanation for the apparent prevalence of market share allocations relative to customer or geographic allocations by explicit cartels.

Keywords: explicit collusion, tacit collusion, price fixing, antitrust, trade associations

JEL Classifications: C72, L13, L41

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1 Introduction

“Fixing market shares is probably the most efficient of all methods of combating secret price reductions. No one can profit from price-cutting if he is moving along the industry demand curve, once a maximum profit price has been chosen. With inspection of output and an appropriate formula for redistribution of gains and losses from departures from quotas, the incentive to secret price-cutting is eliminated. Unless inspection of output is costly or ineffective (as with services), this is the ideal method of enforcement” (Stigler, 1964, p.46)

Stigler (1964), with its numerous themes and messages, is one of the most important papers in the field of industrial organization. Green and Porter (1984), which is also seminal, is a derivative of Stigler (1964). Yet, many of the messages of Stigler’s groundbreaking work have faded because they have not been sufficiently developed. This paper is an attempt to follow up on one remarkable but underdeveloped theme in Stigler’s paper, the prevalence of market share allocations among explicit cartels.

Although market share allocations are prevalent among explicit cartels, geographic allocations and customer allocations, as well as combinations of these with market share allocations, are observed in practice.¹ These cartel organizations have different properties when it comes to the ease of monitoring compliance, the need for updates to the agreement over time, the susceptibility of the cartel’s sustainability to outside entry, and the variability of the share of cartel surplus captured by various cartel members over time. We argue in the next section of this paper that a market share allocation may be a superior choice as

¹For legal opinion related to these cartel organizations, see paragraph 9 of *United States v. Sutar Roofing, Inc.*, 897 F.2d 469 (10th Cir. 1990), which states: “Consistent with the analysis of the Supreme Court and previous holdings of this court and of other circuits, we concur with the determination of the trial court and hold that the activity alleged in the indictment in this case, an agreement to allocate or divide customers between competitors within the same horizontal market, constitutes a per se violation of Sec. 1 of the Sherman Act. See *United States v. Topco Assocs., Inc.*, 405 U.S. 596, 608, 92 S.Ct. 1126, 1133, 31 L.Ed.2d 515 (1972) (“[o]ne of the classic examples of a per se violation of Sec. 1 is an agreement between competitors at the same level of the market structure to allocate territories in order to minimize competition”); *United States v. Goodman*, 850 F.2d 1473, 1476 (11th Cir.1988) (“customer allocation agreement alone is a per se violation of 15 U.S.C. Sec. 1”) (citing *United States v. Cadillac Overall Supply Co.*, 568 F.2d 1078, 1090 (5th Cir.), cert. denied, 437 U.S. 903, 98 S.Ct. 3088, 57 L.Ed.2d 1133 (1978)); *United States v. Cooperative Theatres of Ohio, Inc.*, 845 F.2d 1367, 1372 (6th Cir.1988) (“customer allocation ... is the type of ‘naked restraint’ which triggers application of the per se rule of illegality”); *Mid-West Underground Storage, Inc. v. Porter*, 717 F.2d 493, 497-98 n. 2 (10th Cir.1983) (“[t]he essence of a market allocation violation ... is that competitors apportion the market among themselves and cease competing in another’s territory or for another’s customers”); *United States v. Koppers Co.*, 652 F.2d 290, 293 (2d Cir.), cert. denied, 454 U.S. 1083, 102 S.Ct. 639, 70 L.Ed.2d 617 (1981).”

long as compliance with the agreement can be monitored. We examine the question of the monitoring of a market share allocation and show that in some environments the necessary monitoring can be accomplished through the “legal” assistance of a trade association. According to Burns (1936, p.58), “One important further consequence of providing statistics of total production at very short intervals is that each member is enabled to calculate the extent to which changes in his volume of business are paralleled by changes in the total volume, i.e., whether his share of the total is changing or not; the Department of Commerce approved of this use of the statistics.”² Thus, the legal facilitation by a trade association fills in the last piece of the puzzle for a market share cartel.

We reviewed the twenty major industrial-product cartel decisions of the European Commission between 2000 and 2005.³ For nine of these cartels the authors of the EC decisions report that a trade association (or a technical standards committee, or a “consulting firm”) played an important role in providing information for cartel members.⁴ The nine decisions reporting a role for a trade association are Amino Acids, Carbonless Paper, Citric Acid, Copper Plumbing Tubes, Electrical and Mechanical Carbon and Graphite Products, Industrial and Medical Gases, Industrial Tubes, Organic Peroxides, and Zinc Phosphate. In all but one of these cases (Industrial and Medical Gases), the cartel organization involved a market share allocation. Viewed another way, of the fifteen cases where a market share allocation

²On the legality of a trade association providing such information, Sullivan and Harrison (1988) state at p.98 that: “A review of the important Supreme Court cases on data dissemination indicates that the Court is inclined to approve an exchange of *past* data in summary or aggregate form which do not disclose individual transactions or customers, (1) where there is no disclosure of present or future information, (2) where there are no enforcement or coercive mechanisms that pressure the membership, (3) where the data are available to nonmembers for reasonable fees, or at least to those that have a ‘commercial need to know’ or would be at a competitive disadvantage without the information, and (4) where the market structure of the industry suggests that it is not highly concentrated or tending towards collusion.”

For additional commentary, see Henry (1994). The rule-of-reason applies for information-pooling agreements. The exchange of information is not illegal per se (American Column, 1921; Linseed Oil, 1923; Maple Flooring, 1928; First Cement, 1925). To be challenged, it must restrict competition or help firms to reach agreements on prices. However, sharing of firm-specific data is suspicious (American Column, 1921; Linseed Oil, 1923). Sharing of aggregate, anonymous, and historical data does not necessarily raise objections, even though it may bring about a certain uniformity of action in the industry (Maple Flooring, 1928; First Cement, 1925).

The parties to the EC decision in Organic Peroxides argued that the legality of a trade association providing aggregate statistics extends to private consulting firms hired by industry members (EC decision at footnote 49).

³The twenty cases are detailed in the Appendix. Complete references for the EC decisions cited in this paper are given in Table A.1.

⁴The lack of mention of a trade association in an EC decision does not imply that the cartel did not use or rely on one to conduct its business. The authors of the EC decision may have provided a narrow description of the cartel’s conduct.

was a component of the cartel's organization, eight mention a role for a trade association.

Our model begins with an oligopoly framework not unlike Green and Porter (1984), but is based on price competition. Stochastic demand shocks can occur each period. As in Green and Porter, there is no way for the firms to avoid equilibrium-path punishment phases under tacit collusion. As in Porter (1983), the optimal tacitly collusive trigger-strategy equilibrium may not achieve the monopoly outcome, even during periods of cooperation.

To model explicit collusion, we begin by assuming firms can credibly communicate their market outcome to a single firm that acts as a clearinghouse for such information. We show that the collusive outcome can be sustained in this environment if the firms use transfers. We then increase the degree of information sharing by assuming that all firms can credibly communicate their market outcomes to one another. In this case, the monopoly outcome can be sustained even without the use of transfers. Finally, we assume that communication is restricted to flow through a trade association, which can only report industry aggregates. We give conditions under which this is sufficient to sustain the monopoly outcome.

In our model, a market share allocation arises naturally since, with the report from the trade association, cartel members can detect whether their own market shares have changed, and thus whether there was cheating on the collusive agreement. Therefore, with this limited information exchange and a market share allocation, the firms are able to eliminate all punishment periods associated with tacit collusion and increase payoffs in cooperative periods to the monopoly outcome.

Other authors considering collusion in an environment with repeated price competition include Tirole (1988), Athey and Bagwell (2001), Bagwell and Wolinsky (2002), Athey, Bagwell, and Sanchirico (2004), and Harrington and Skrzypacz (2007).⁵ Tirole (1988) and Bagwell and Wolinsky (2002) consider models of tacit collusion based on Bertrand price competition, where firms' prices and quantities are private information. As in our benchmark model of tacit collusion, under certain conditions trigger strategies can be used to support behavior in non-punishment periods that maximizes the expected joint stage-game payoffs.⁶ Harrington and Skrzypacz (2007) consider a model of explicit collusion in which firms' prices are private information, but quantities are public information, and total demand is fixed.

⁵Blume and Heidhues (2008) and Skrzypacz and Hopenhayn (2004) focus on collusion in repeated single-unit auctions. For an example of a bidding cartel operating in a repeated auction context, see Asker (2007). On the problem of identifying and testing for bid rigging, see Bajari and Summers (2002) and Bajari and Ye (2003).

⁶The underlying logic is that of the Folk Theorem (see Friedman, 1971; and Fudenberg and Maskin, 1986).

Their results highlight differences between environments with symmetric versus asymmetric cartel punishments. Athey and Bagwell (2001) and Athey, Bagwell, and Sanchirico (2004) assume perfect monitoring of prices and quantities and consider a range of collusive environments, including environments with and without communication and with and without transfer payments among firms. They allow individual cost shocks that are private information and provide results on the efficiency and payoff properties of equilibrium outcomes.

The paper proceeds as follows. We begin by discussing the prevalent use by explicit cartels of market share allocations in Section 2. Section 3 describes the basic components of the model and develops the benchmark case of tacit collusion. In Section 4, we move to an environment of explicit collusion, which involves information sharing and transfers among the colluding firms. Section 5 focuses on the role of a market share allocation as a component of an explicitly collusive equilibrium. Section 6 concludes with a discussion of longer-run effects of an explicit cartel's ability to share information and make transfers. In particular, these arrangements may allow the cartel firms to undertake projects that increase the cartel's profitability that no individual firm would undertake on its own.

2 Cartel organization

We focus on three cartel organizations: a customer allocation, a geographic allocation, and a market share allocation. These three cartel organizations are highlighted in Posner (1976, p.62), where he states,

“If the major firms in a market have maintained identical or nearly identical market shares relative to each other for a substantial period of time, there is good reason to believe that they have divided the market (whether by fixing geographical zones or sales quotas or by an assignment of customers), and thereby eliminated competition, among themselves.”

A customer allocation within an explicit cartel assigns specific customers to specific cartel members. A geographic allocation within an explicit cartel specifies geographic areas where specific cartel members can and cannot sell product.⁷ A market share allocation among members of an explicit cartel specifies the maximum shares of within-cartel sales that each cartel member is allowed in the market for a given time period. Combinations of these cartel

⁷On geographic patterns of trade and home bias in a non-collusive setting, see Hortaçsu, Martinez-Jerez, and Douglas (2006).

allocations are possible and observed. For example, explicit cartels often allocate a country where a member has production facilities exclusively to that producer (geographic allocation) but apply a market share allocation in regions where there is no cartel production.

Table 1 contrasts these three cartel allocation schemes in terms of their ease of monitoring compliance, the need for updates to the agreement over time, the susceptibility of cartel sustainability to outside entry, and the variability of the share of cartel surplus captured by various cartel members over time.

As shown in the table, a market share allocation may be a superior choice as long as compliance with the agreement can be monitored.

Table 1: Comparison of Cartel Organizations

Organization	Requirements	Monitoring	Disruptions*	Outside Entry	Share of Cartel Surplus**
Customer allocation	Customers known in advance	Easy	Changes in customer identities	Causes reallocation	Affected by changes in relative sizes of customers
Geographic allocation	Sales are associated with locations	Varies	Changes in trade regulations and boundaries	Causes reallocation	Affected by changes in relative growth of areas
Market share allocation	-	?	-	No within-cartel reallocation	Stable

*In all cases, the cartel is affected by changes in the membership of the cartel itself. We focus on external factors causing disruptions.

**In all cases, a cartel may choose to change cartel members' relative shares. We focus on external factors forcing such a change.

In what follows, we discuss aspects of each cell in this table. The requirements column is fairly straightforward. A cartel cannot allocate customers if the identities of the customers are not known in advance of the sales, and it is not meaningful for a cartel to allocate geographic areas if individual sales cannot be associated with a particular geographic area. No special requirements are necessary for a cartel to agree to fixed within-cartel market shares.

The remaining four columns deserve more detailed discussion. We address these in turn in the following four subsections. We summarize in Section 2.5.

2.1 Monitoring

With a customer allocation, if each customer single sources, each firm need only observe that it is selling to the customers allocated to it. If a customer multiple sources, then it may be necessary to verify firms' shares of a customer's purchases.⁸ A buyer may have an incentive to allow a supplier to audit its purchases if the audit is required in order for the buyer to obtain rebates based on the share it purchases from the supplier.

With a geographic allocation, if each producer is in a separate country and import/export statistics and other information about cross-border trade is readily available or if there are restrictions on cross-border trade, then monitoring can be straightforward.⁹ If it is known which customers are in which geographic areas and if customers single source, then each firm need only observe that it is selling to the customers in the geographic area allocated to it. Monitoring is more difficult if customers are not fixed and/or it is difficult to monitor the flow of goods across geographic boundaries.

With a market share allocation monitoring might appear to be a daunting task. If producers are located in the same country, and that country is a large market, then cross-border trade will not provide sufficient information to enforce a global market share allocation. Monitoring may also be encumbered if customers multiple source. A global market share allocation requires that the cartel's total market size be assessed and communicated to cartel members so each cartel member can ascertain whether it has achieved its agreed-to market share.

In this paper, we examine explicit collusion based on a market share allocation under three different monitoring regimes.¹⁰ We first assume firms can credibly communicate their

⁸One possibility is to use fidelity rebates based on market shares, with associated audits, to verify shares.

⁹The EC decision in *Copper Plumbing Tubes* at paragraph 622 states, "However, for certain durations and countries, control was facilitated by export statistics." The same decision at paragraph 144 states, "At least until 1995, monitoring was facilitated by national certification procedures. Copper plumbing tubes had to be certified in each Member State. Each Member State had its own certification label. Certification organisations ... prohibited producers at least until 1995 to indicate different national certifications on plumbing tubes."

Patent licensing agreements can also facilitate monitoring. As stated in the Temporary National Economic Committee (TNEC), *Hearings, Part 25, Cartels*, Washington, DC: U.S. Government Printing Office, 1941, at p.13341: "In the incandescent electric lamp industry, ... the Westinghouse Electric Co. pays the General Electric Co. a royalty of 1 percent on sales of lamps which do not exceed 25.4 percent of the combined lamp sales of the two concerns. It pays a royalty of 30 percent on sales made in excess of this. ... The five other licensed assemblers are prohibited from making and selling lamps for export. They pay a royalty of 3 1/3 percent on lamp sales which do not exceed a certain percentage of General Electric sales. They are required to pay an additional royalty of 20 percent on sales made in excess of their stipulated shares."

¹⁰Cartels have often found ways to monitor members. In discussing the International Steel Cartel of the late 1930's, Hexner (1943, p.95) states, "One should realize that violations which occurred sometimes

market outcome to a single firm that acts as a clearinghouse for such information.¹¹ For example, the EC decision in Amino Acids at paragraph 122 states, “ADM named Ajinomoto as the office to which each lysine producer would provide monthly sales figures.”¹²

Second, we increase the degree of information sharing by assuming that all firms can credibly communicate their market outcomes to one another. For example, Stocking and Watkins (1991, p.335) state that in the Incandescent Lamp Cartel, “Each member was required to throw open his plants and research laboratories to the inspection of any member.”¹³

Third, we assume that communication is restricted to flow through a trade association, which can only report industry aggregates.¹⁴ For example, the EC decision in Zinc Phosphate at paragraph 35 states, “Over the time period considered in this Decision, the five main European producers of zinc phosphate exchanged information and met within trade associations. These trade associations collected and compiled the sales data of each individual company and informed them in return about the size of the market.”¹⁵

To ensure the accuracy of the statistics it reports, some trade associations audit the firms’ reported information.¹⁶ For example, The EC decision in Amino Acids at paragraph 100

happened many thousands of miles from the centers of cartel activities. However, more often than one might suppose, infringements of cartel regulations were reported by competing distributors within a few hours, even if they occurred in the most remote regions of the world.”

¹¹Hay (1982, p.454) describes the possibility of effective collusion with asymmetric information sharing: “For purposes of accomplishing the oligopoly tasks, the exchange of information need not be symmetrical. That is, the oligopolists may benefit as a group even if only some firms unilaterally provide information about their own activities.”

¹²In other examples, the EC decision in Organic Peroxides at paragraph 128 states, “Shortly before each quarterly meeting, one of the participants on a rotating basis would receive the date [sic] from the two other participants.” In addition, the EC decision in Citric Acid at paragraph 85 states, “each company would report its monthly sales figures to [a Roche executive’s] secretary in Basel, who would then contact the companies and provide each company’s sale figures for the corresponding month. ... since the sales of the four companies made up a significant part of total ECAMA sales, the regular report of which provided aggregate sale figures, this could be used to identify any company that gave incorrect data.”

¹³In another example, the EC decision in Specialty Graphite at paragraph 101 states, “In addition, the frequent exchanges of shipment records among competitors [cartel members] allowed a detailed monitoring of sales and the detection of possible deviations to the cartel instructions.”

¹⁴Exhibit No. 2176 of the TNEC (1941) *Hearings* on cartels (pp.13573–13574) is a public statement from the Department of Justice Division for Enforcement of Antitrust Laws released June 27, 1939. It states, “The Department’s preliminary investigation indicates that certain trade associations not only disseminate production statistics but take steps to see that their members produce no more of the total supply than these statistics indicate has been their proportionate share.”

¹⁵In another example, the EC decision in Organic Peroxides at paragraph 92 describes the Zurich-based firm AC Treuhand as performing the following functions (among others): “organised the auditing of the data submitted by the parties” and “collected data on OP sales and provided the participants with the relevant statistics.”

¹⁶According to Clark (1983, p.927), “In the typical case, an industry trade association is authorized to collect detailed information on the transactions executed by each member. To ensure full compliance, the

states, “ADM stated that the way for them to communicate is through a trade association. ADM explained by way of example that ADM reported its citric acid sales every month to a trade association, and every year, Swiss accountants audited those figures.” Alternatively, the association might require firms to post bonds that are forfeit if the firm is caught not reporting truthfully.¹⁷ Stocking and Watkins (1991) describe the use of bonds in the “common fund” of the Steel Cartel (p.183), the “guarantee deposits” of the Aluminum Alliance (p.232), and the “indemnity funds” deposited at a Swiss corporation by the Incandescent Electric Lamp Cartel (p.337).

Henry (1994, p.503) suggests that there may even be antitrust benefits associated with using a trade association: “Employing an independent third party to undertake data collection, compilation, and dissemination can significantly decrease the antitrust risk. Third parties eliminate the need for direct contact between the information providers and, thus, reduce the risk of collusion. Moreover, third parties can aggregate the data so that particular information providers are not identifiable.” We show that, although it may be legally permissible for a trade association to report data in aggregate form, the fact that data is aggregated is not sufficient to prevent that information exchange from being an important facilitator of collusion.

We do not mean to suggest that the exchange of *any* information through a trade association is legal, nor are we arguing that because the exchange and dissemination of certain information through a trade association is legal, it could not be part of an illegal collusive mechanism. It has long been recognized the practices of a trade association may lead to the suppression of competition and that any such practices would be considered a violation of the antitrust laws.¹⁸

association or an independent auditing firm is sometimes empowered to audit company records, and fines may be levied for failure to report sales quickly or accurately.”

¹⁷Commenting on cartels’ use of bonds, Hexner (1943, p.102) states, “According to the EIA [continental European steel cartel] agreement, the management committee fixed rather high deposits, placed in the custody of the EIA business agency in Luxemburg, which were intended to insure the orderly fulfillment of obligations assumed with membership in the EIA and in the comptoirs closely connected with it.”

¹⁸See, e.g., the 1922 letter from Attorney General H. M. Daugherty to Secretary of Commerce Herbert Hoover stating, “Therefore the expression of the view that the [trade association practices] enumerated by you, with the exceptions stated, may be done lawfully is only tentative; and if in the actual practice of any of them it shall develop that competition is suppressed or prices are materially enhanced, this Department must treat such a practice as it treats any other one which is violative of the Anti-Trust Act.” (Jones, 1922, p.333)

2.2 Disruptions

A customer allocation must specify individual customers. However, customers can come and go. Entry, exit, mergers, and divestitures can change the set of existing customers. These changes create a need for updates to an explicit cartel's customer allocation.

Updates to a geographic allocation may also be called for if changes in the regulatory or political environment, e.g., boycotts, wars, tariffs, etc., make it difficult or costly for a particular cartel member to serve a particular geographic area. Although relatively uncommon, changes in national boundaries can create a need for updates of geographic allocations.

A market share allocation need not be invalidated by changes in the environment.

2.3 Outside entry

For a cartel operating under a customer allocation, outside entry causes a reallocation of cartel surplus among the cartel members unless non-cartel entrants serve customers allocated to the various cartel members in equal proportion. For a geographic allocation, outside entry causes a reallocation of cartel surplus among the cartel members unless outside entrants serve the same proportion of each cartel member's geographic area.

For a cartel operating under a market share allocation, non-cartel entry need not cause a reallocation. Outside entry reduces the overall surplus available to the cartel members but does not require a reallocation of the within-cartel market shares.

2.4 Share of cartel surplus

The smooth function of a cartel can be disrupted if a cartel member believes that it is being relatively disadvantaged by an exogenous shift in the marketplace or economic environment. Thus, it can be important for the sustainability of a cartel that the cartel members' relative shares of the collusive surplus remain equitable.

In a dynamic environment, one would not expect customers' demands to vary in exact proportion to one another, so the share of cartel surplus captured by the various cartel members under a customer allocation would be expected to change over time. Similarly, in a dynamic environment, one would not expect the demand in various geographic areas to vary in exact proportion to one another, so the share of cartel surplus captured by the various cartel members under a geographic allocation would be expected to change over time. However, with a market share allocation, cartel members' shares of the cartel surplus remain

constant over time.

2.5 Summary

To summarize, if we return to Table 1, we see that a customer allocation, when it is feasible, may be desirable because of the ease of monitoring. However, a customer allocation has a number of undesirable properties when the set of customers or their relative sizes change over time or if cartel price increases induce non-cartel entry.

In some cases, monitoring can also be straightforward for a geographic allocation, so that organization may be desirable as well. However, a geographic allocation can fare poorly in some political environments or when the relative purchases of different geographic areas vary over time or there is non-cartel entry.

Because both customer allocations and geographic allocations have desirable properties for a cartel in certain environments, we might expect to observe these organization in use. For example, a customer allocation was a component of the cartel agreement in several EC cases (see Table A.2 in the Appendix). A geographic allocation was also a component of several EC cases and was used in *Tuscaloosa v. Harcross* 158 F.3d 548 (11th Cir. 1998), where providers of repackaged chlorine were alleged to have allocated contracts in geographic markets, and in *U.S. v. Koppers*, where two road construction firms divided the state of Connecticut between them:

“Arthur Schuck, Koppers’ manager of its eastern road materials district, made a proposal to Dosch-King in 1967 that the two firms divide the state between them so that Dosch-King would be the low bidder in the western part of Connecticut, where its activities were concentrated, and Koppers would be the low bidder in the eastern part, where its storage facility and distribution point were located.”¹⁹

As shown in Table 1, as long as a cartel can effectively monitor a market share allocation, it appears to dominate the other cartel organizations considered there. As we show in the remainder of this paper, effective monitoring is possible if the cartel can enlist a trade association to collect data on cartel output and disseminate aggregate information to the cartel members.²⁰

¹⁹*United States v. Koppers Co.*, 652 F.2d 290 (2d Cir. 1981) at paragraph 4.

²⁰Before continuing to the next section, however, it may be useful to be clear about some things we are *not* arguing in this paper. We are not arguing that collusion cannot be effective without a market share allocation. As described above and in the Appendix, effective cartels have used other organizations, including, but not

3 Benchmark—Tacit collusion

We consider a model with n firms that interact repeatedly over an infinite time horizon, $t \in \{0, 1, \dots\}$. We assume the firms have a common discount factor $\delta \in (0, 1)$. Firm i 's strategy set in the stage game is S_i , which is constant over time. The stage game payoff for firm i in period t is $\pi_i(s, \varepsilon_t)$, where $\pi_i : \times_{j \in N} S_j \times \Omega \rightarrow \mathbb{R}$, s is the profile of strategy choices in period t , and $\varepsilon_t \in \Omega$ is a random variable that is i.i.d. across time and common to all firms. We assume Ω is a closed, bounded interval in \mathbb{R} and that the distribution of ε_t has positive density on the interior of Ω .

In each period t , the firms' strategies, together with the shock ε_t , generate a “market outcome” for firm i of $m_i : \times_{j \in N} S_j \times \Omega \rightarrow M$. We assume that firm i 's market outcome captures the effect on firm i 's payoff of both the shock ε_t and the rival firms' strategies. Thus, there exist functions $\hat{\pi}_i : S_i \times M$ such that if $\hat{m}_i = m_i(s, \varepsilon_t)$, then $\hat{\pi}_i(s_i, \hat{m}_i) = \pi_i(s, \varepsilon_t)$.

Our main application is to an environment with price competition. In this application, a firm's strategy is its price, and a firm's market outcome is the quantity it sells, which depends on firm i 's price and its rivals' prices, as well as the shock. Thus, even though a firm's market outcome depends on the other firms' strategies, its payoff depends only on its own strategy and its market outcome. In Section 5, we expand the firms' strategy spaces to include sales effort.

The timing within each period is as follows: (i) firms simultaneously choose strategies, (ii) each firm observes its own payoff and its own market outcome.

We let strategy profile s^e be an equilibrium of the stage game, with expected stage game payoffs $E_{\varepsilon_t} [\pi_i(s^e, \varepsilon_t)]$. Define $\Pi(s) \equiv E_{\varepsilon_t} [\sum_{i=1}^n \pi_i(s, \varepsilon_t)]$, which is the expected joint stage-game payoff of the n firms given their strategies.

Let $s^* \in \arg \max_s \Pi(s)$ be the optimal cartel strategies, which we assume are unique. We assume that for each firm i , $E_{\varepsilon_t} [\pi_i(s^*, \varepsilon_t)] > E_{\varepsilon_t} [\pi_i(s^e, \varepsilon_t)]$ so that each firm's expected stage-game payoff increases if the firms choose “collusive” strategies s^* rather than the “noncooperative strategies” s^e .

We assume that for each firm i there exists s_i^d such that $E_{\varepsilon_t} [\pi_i(s_i^d, s_{-i}^*, \varepsilon_t)] > E_{\varepsilon_t} [\pi_i(s^*, \varepsilon_t)]$, so that a one-shot deviation by firm i from an agreement to play s^* increases firm i 's expected stage-game payoff. We also assume that for all s_i^d such that $E_{\varepsilon_t} [\pi_i(s_i^d, s_{-i}^*, \varepsilon_t)] >$

limited to, customer and geographic allocations. We are also not arguing that collusion cannot be effective in the absence of a trade association. Clearly it can—see the EC decision in Vitamins and other cases listed in the Appendix. The analysis of a particular cartel must take into account the specifics of the particular mechanism used by that cartel.

$E_{\varepsilon_t} [\pi_i(s^*, \varepsilon_t)]$, and all $\varepsilon_t \in \Omega$, there exists $\varepsilon'_t \in \Omega$ such that

$$(\pi_{-i}(s_i^d, s_{-i}^*, \varepsilon_t), m_{-i}(s_i^d, s_{-i}^*, \varepsilon_t)) = (\pi_{-i}(s^*, \varepsilon'_t), m_{-i}(s^*, \varepsilon'_t)). \quad (1)$$

Thus, the profit and market outcome observed by firms other than i is the same when firm i deviates by choosing s_i^d and the shock is ε_t , as it is when firm i does not deviate, but the shock is ε'_t . In the case of price competition, this assumption says that a firm cannot distinguish the undercutting of its price by a rival firm from a negative demand shock.²¹

Now suppose that there is a tacitly collusive equilibrium of the infinitely repeated game in which the firms choose strategies s^* in all periods on the equilibrium path for all realizations of the shock.²² This implies that for all $\varepsilon_t \in \Omega$, if firm $j \neq i$ observes $(\pi_j(s^*, \varepsilon_t), m_j(s^*, \varepsilon_t))$, then firm j chooses strategy s_j^* in the next period. But then, firm i can profitably deviate by choosing strategy s_i^d since it increases its expected payoff and, using (1), does not trigger a response by the other firm. This proves the following result.

Proposition 1 *There is no tacitly collusive equilibrium in which firms maximize their expected joint stage-game payoff in every period on the equilibrium path.*

Proposition 1 implies that under a tacitly collusive agreement, there must be punishments on the equilibrium path, and so the cartel's discounted expected payoff is less than $\frac{1}{1-\delta}\Pi(s^*)$. In particular, with positive probability there must be some periods in which firms use strategies other than s^* .

3.1 Trigger strategies under price competition

Possible tacitly collusive equilibria include equilibria in which certain market outcomes trigger a Nash-reversion punishment phase as in Porter (1983) and Green and Porter (1984),²³

²¹In Green and Porter's (1984) model, a low market price can be the result of a deviation by another firm or a negative demand shock.

²²We define tacit collusion to be non-cooperative infinitely repeated play. However, Green and Porter (1984) note in their footnote 5, "It is logically possible for this agreement to be a tacit one which arises spontaneously. Nevertheless, in view of the relative complexity of the conduct to be specified by this particular equilibrium and of the need for close coordination among its participants, it seems natural to assume here that the equilibrium arises from an explicit agreement."

²³The use of reversion to pre-collusive play as a punishment for deviations from collusion is explicitly mentioned in Congressional testimony involving dyestuffs manufacturers (*Patents: Hearings before the Committee on Patents*, United States Senate, Seventy-Seventh Congress, Second Session, on S. 2303 and S. 2491, Part 5, May 13 and 16, 1942, United States Government Printing Office, 1942, p.2424). The testimony includes a letter from a foreign sales manager of a dyestuffs manufacturer stating: "You and your contemporaries

and other equilibria involve more sophisticated stick-and-carrot strategies as in Abreu (1986) and Abreu, Pearce, Stacchetti (1986, 1990).

Depending on the discount factor and other parameters, there may exist tacitly collusive equilibria in which firms choose strategy profile s^* in some periods on the equilibrium path. However, as discussed in Green and Porter (1984), there may not exist a Nash reversion, trigger-strategy equilibrium in which firms play s^* in the non-punishment periods. Furthermore, even if such equilibria exist, as shown in Porter (1983), the joint-payoff-maximizing equilibrium of that type may require that firms use strategies other than s^* in the non-punishment periods.

To provide a simple formalization of these ideas, we consider an environment with symmetric firms, homogeneous products price competition, and constant marginal cost. Under these assumptions, the Nash equilibrium of the stage game is for all firms to choose price equal to marginal cost, and so $\pi_i(s^e, \varepsilon_t) = 0$.

In order for each firm to have positive sales under collusion, it must be that all firms choose the same price, i.e., $s_i^* = s_1^*$ for all i . A firm deviating to a price above s_1^* has zero payoff, and a firm deviating to a price below s_1^* captures all the sales and so has payoff bounded above by $n\pi_1(s^*, \varepsilon_t)$. We assume the shock ε_t affects the firms symmetrically, so if the shock is sufficient to drive sales to zero for one firm, it also drives sales to zero for the other firms.

Consider a tacitly collusive Nash-reversion, trigger-strategy equilibrium as in Green and Porter (1984). Classify periods as either punishment periods or non-punishment periods. To begin, assume the punishment continues indefinitely once it is triggered.

If a firm deviates by charging price below s_1^* , all other firms will have zero sales. So any trigger-strategy equilibrium in this environment must involve punishment periods following any period in which at least one firm observes zero sales. If a firm observes zero sales, it knows that either there was a sufficiently negative demand shock and all firms had zero sales, or one or more of the other firms deviated and undercut the collusive price, in which case all non-deviating firms observe zero sales. In either case, following such a period, it is common knowledge that the next period is a punishment period.

Thus, the first period, $t = 0$, is a non-punishment period, and for $t \geq 1$ period t is a punishment period if in any period prior to t , any firm has a market outcome of zero.

should be in a position to establish market prices based upon definite strength determination of color, which prices should be followed by you if such an understanding is reached. But, if you have any indication that a contemporary is not adhering to such prices, then immediately revert to the prices prevailing before any arrangements were established.”

Consider whether a firm can profitably deviate from strategies specifying that they choose the expected joint-payoff maximizing strategy profile s^* in non-punishment periods and the stage-game Nash equilibrium s^e in punishment periods. Let $\rho(s_i) \equiv \Pr[\min_{j \neq i} m_j(s_i, s_{-i}^*, \varepsilon_t) = 0]$ be the probability that a punishment phase is triggered when firm i chooses s_i and firms other than i choose s_{-i}^* . Note that $\rho(s_i) = 1$ for $s_i < s_i^*$ since a deviation triggers a punishment phase with certainty, but we assume $\rho(s_i^*) \in (0, 1)$ so that there is positive probability that a punishment is triggered even when firms choose s^* .

Assuming no deviations, firm i 's expected payoff is

$$\begin{aligned} V^*(\delta) &\equiv \frac{E_{\varepsilon_t} [\pi_i(s^*, \varepsilon_t)] + \frac{\delta}{1-\delta} \rho(s_i^*) E_{\varepsilon_t} [\pi_i(s^e, \varepsilon_t)]}{1 - \delta (1 - \rho(s_i^*))} \\ &= \frac{E_{\varepsilon_t} [\pi_i(s^*, \varepsilon_t)]}{1 - \delta (1 - \rho(s_i^*))}. \end{aligned}$$

Firm i 's expected payoff from choosing $s_i < s_i^*$ in one period and then returning to equilibrium play in the ensuing punishment phase is

$$\begin{aligned} V(s_i; \delta) &\equiv E_{\varepsilon_t} [\pi_i(s_i, s_{-i}^*, \varepsilon_t)] + \frac{\delta}{1-\delta} E_{\varepsilon_t} [\pi_i(s^e, \varepsilon_t)] \\ &= E_{\varepsilon_t} [\pi_i(s_i, s_{-i}^*, \varepsilon_t)] \\ &< n E_{\varepsilon_t} [\pi_1(s^*, \varepsilon_t)]. \end{aligned}$$

Since $\lim_{\delta \rightarrow 1} V^*(\delta) = \frac{1}{\rho(s_1^*)} E_{\varepsilon_t} [\pi_1(s^*, \varepsilon_t)]$, the deviation is not profitable as long as δ is sufficiently large and $\rho(s_1^*) < \frac{1}{n}$, giving us the following result.

Proposition 2 *Assuming homogeneous products price competition with symmetric firms with constant marginal cost, there exists a tacitly collusive equilibrium in which firms maximize their expected joint stage-game payoff in some periods on the equilibrium path if and only if δ is sufficiently close to one and $\rho(s_1^*) < \frac{1}{n}$.*

Proof. The proof of sufficiency follows from the discussion in the text. For the proof of necessity, note that for δ sufficiently low, the incentives for short-run deviations dominate, regardless of the punishment strategy employed, since in a tacitly collusive equilibrium, punishment payoffs are bounded below. If $\rho(s_1^*)$ is sufficiently large, then punishments are triggered with sufficiently high probability that again incentives for short-run deviations dominate. Q.E.D.

3.2 Optimal trigger strategies under price competition

Although Proposition 2 shows that the strategies that maximize the expected joint payoff in the stage game can be achieved in some periods (non-punishment periods) in tacitly collusive equilibria, such equilibria may not be optimal for the tacitly colluding firms. It may be that the *optimal* tacitly collusive agreement requires that firms choose strategies in non-punishment periods other than those that maximize their expected joint stage-game payoff. By choosing strategies with a lower joint payoff, it may be possible to reduce the incentive for firms to deviate, thereby allowing the firms to sustain cooperation with less severe punishments. In a model with quantity competition, Porter (1983) shows that whenever the optimal trigger-price mechanism in his model involves interior values for the trigger price and length of punishment, then it involves using strategies in non-punishment periods that result in an expected joint payoff that is less than its maximum. Our analysis with price competition is similar to the analysis of Tirole (1988, Section 6.7.1.1).

Since we focus on symmetric equilibria, we can simplify notation by letting $\tilde{\pi}(s_i) \equiv E_{\varepsilon_t} [\pi_i(s_i, \dots, s_i, \varepsilon_t)]$ and $\tilde{\rho}(s_i) \equiv \Pr [m_i(s_i, \dots, s_i, \varepsilon_t) = 0]$.

We now allow finite punishment lengths. If the punishment phase lasts for only $T - 1$ periods, then a firm's expected payoff when firms choose s_i is

$$\frac{\tilde{\pi}(s_i)}{1 - (1 - \tilde{\rho}(s_i))\delta - \tilde{\rho}(s_i)\delta^T}.$$

The optimal symmetric tacitly collusive equilibrium of this type is defined by \tilde{s}_i and \tilde{T} that solve

$$(\tilde{s}_i, \tilde{T}) \in \arg \max_{s_i, T} \frac{\tilde{\pi}(s_i)}{1 - (1 - \tilde{\rho}(s_i))\delta - \tilde{\rho}(s_i)\delta^T} \quad (2)$$

subject to the incentive compatibility constraint that

$$\frac{\tilde{\pi}(\tilde{s}_i)}{1 - (1 - \tilde{\rho}(\tilde{s}_i))\delta - \tilde{\rho}(\tilde{s}_i)\delta^{\tilde{T}}} \geq n\tilde{\pi}(\tilde{s}_i) + \delta^{\tilde{T}} \frac{\tilde{\pi}(\tilde{s}_i)}{1 - (1 - \tilde{\rho}(\tilde{s}_i))\delta - \tilde{\rho}(\tilde{s}_i)\delta^{\tilde{T}}},$$

or equivalently,

$$\delta^{\tilde{T}} \geq \frac{n - 1 - n(1 - \tilde{\rho}(\tilde{s}_i))\delta}{n\tilde{\rho}(\tilde{s}_i) - 1}. \quad (3)$$

Note that (3) must bind because otherwise the punishment length could be shortened. Using (3) to substitute into the maximand in (2), we can find the optimal collusive price by

solving

$$\tilde{s}_i \in \arg \max_{s_i} \frac{1}{1-\delta} \frac{1-n\tilde{\rho}(s_i)}{1-\tilde{\rho}(s_i)} \tilde{\pi}(s_i). \quad (4)$$

It is clear from this expression that the optimal price does not depend on the discount factor. Also, this expression is positive as long as $\tilde{\rho}(s_i) \in [0, \frac{1}{n})$, i.e., for an equilibrium price sufficiently small.

For example, if we assume zero marginal cost and linear demand $D(p) = \max\{0, 1-p-\varepsilon_t\}$, where ε_t is uniformly distributed on $[0, 1]$, then

$$\tilde{\pi}_i(p) = \int_0^{1-p} \frac{1}{n} (1-p-\varepsilon) p d\varepsilon = \frac{1}{2n} p(1-p)^2,$$

$\tilde{\rho}(p) = \Pr(1-p-\varepsilon_t \leq 0) = p$, and the expected joint-payoff maximizing price is $p^* = \frac{1}{3}$.

Solving (4), we get $\tilde{p} = \frac{1+n-\sqrt{1-n+n^2}}{3n}$, which one can show is less than p^* for all $n \geq 2$. Thus, in the optimal tacitly collusive equilibrium, even in non-punishment periods, firms do not choose the strategies that maximize their expected joint stage-game payoff.

In general, if we assume $\tilde{\pi}$ and $\tilde{\rho}$ are continuously differentiable and that the maximand in (4) is concave, then taking the derivative with respect to s_i and evaluating it at $s_i = s_i^*$, the optimal collusive price is less than s_i^* if

$$\frac{\partial \tilde{\pi}(s_i^*)}{\partial s_i} < \frac{n-1}{(1-\tilde{\rho}(s_i^*)) (1-n\tilde{\rho}(s_i^*))} \frac{\partial \tilde{\rho}(s_i^*)}{\partial s_i} \tilde{\pi}(s_i^*). \quad (5)$$

This proves the following proposition.

Proposition 3 *In an environment with symmetric firms with constant marginal cost engaged in homogeneous products price competition, assuming differentiability and concavity, if (5) holds, then in the optimal tacitly collusive trigger-strategy equilibrium, firms never choose the strategies that maximize their expected joint stage-game payoff.*

To summarize, in this section we show that there are a number of reasons why expected joint profits are not maximized under tacit collusion. First, Proposition 1 shows that firms cannot sustain the optimal stage-game strategies without having punishment periods on the equilibrium path that reduce firms' payoffs. Second, by Proposition 2, even in non-punishment periods the discount factor may prevent there from being any tacitly collusive equilibrium that supports the optimal stage-game strategies. Finally, by Proposition 3, even if the discount factor is sufficiently large that the optimal stage-game strategies can

be supported in a tacitly collusive equilibrium, such an equilibrium may not be the optimal tacitly collusive equilibrium because of the severity of punishments required to support such strategies.

4 Explicit collusion

In this section, we consider explicitly collusive agreements between the firms. Explicit collusion occurs when firms exchange information and/or resources for the purposes of increasing profits through the suppression of interfirm rivalry. Collusion is also explicit if firms formally agree to the strategies they will employ. For example, collusion is explicit if firms communicate an agreement to participate in an otherwise tacitly collusive equilibrium.

We consider different possibilities for the information exchange between explicitly colluding firms. Specifically, we consider different possibilities for firms' abilities to monitor the market outcomes of their rivals.

4.1 One-sided monitoring

In this section, we assume that firm 1 can observe the market outcome of the other firms, but not vice versa; we refer to this environment as one with one-sided monitoring. For example, a firm in country 1 might be able to monitor imports to country 1 and so be able to observe the quantity sold in country 1 by foreign firms, but the foreign firms might not be able to observe how much the domestic firm sells. Or firm 1 might play the role of a ring leader for the cartel and as part of the cartel agreement have the authority to audit the market outcomes of the other firms. Or firm 1 might be a large firm that sells at least some product to each customer and so through fidelity rebates or other contractual agreements have the right to audit the various customers' purchases. See Section 2 for specific examples.

In environments with one-sided monitoring, we show that by using transfers, the firms can achieve the optimal cartel outcome, maximizing the expected joint stage-game payoff in every period on the equilibrium path.

The timing within each period is as follows: *(i)* firms simultaneously choose strategies, *(ii)* each firm observes its own payoff and its own market outcome, *(iii)* firm 1 observes the market outcome of the other firms, and *(iv)* firms make transfers. Related to *(iv)*, we assume firms can observe whether any firm failed to make a required transfer.

The following condition says that deviations for a given strategy profile are detectable

by firm i if firm i can calculate a statistic based on its strategy and market outcome and the markets outcome of the other firms whose value identifies deviations by the other firms.

Definition 1 *Profitable deviations from strategy profile \hat{s} are detectable by firm i if there exists statistic $\sigma_i : S_i \times M^n \rightarrow \mathbb{R}$ and $\hat{\sigma}_i \in \mathbb{R}$ such that for all $\varepsilon_t \in \Omega$, $j \neq i$, and $s_j \in S_j$, $\pi_j(s_j, \hat{s}_{-j}, \varepsilon_t) > \pi_j(\hat{s}, \varepsilon_t)$ implies*

$$\sigma_i(\hat{s}_i, m(s_j, \hat{s}_{-j}, \varepsilon_t)) \neq \sigma_i(\hat{s}_i, m(\hat{s}, \varepsilon_t)) = \hat{\sigma}_i.$$

This definition says that profitable deviations by firm j are detectable by firm i if there is some statistic that firm i can calculate given its information, such that if firm i does not deviate, then the value of the statistic differs from the value $\hat{\sigma}_i$ if and only if firm j deviates. Deviations that are not profitable need not be detected. For example, a sufficiently large negative shock might reduce all firms' quantities to zero, in which case a deviation might not be detectable, but it would also not be profitable.

Note that the definition requires that, when no firm deviates, the value of firm i 's statistic is independent of the shock ε_t . For example, in an environment with heterogeneous products price competition and a common, multiplicative shock, deviations are detectable using as the statistic a firm's market share, $\sigma_i(s_i, m) = \frac{m_i}{\sum_{j=1}^n m_j}$.

We now construct an explicitly collusive equilibrium with one-sided monitoring in which the firms choose strategies that maximize the expected joint stage-game payoff in every period on the equilibrium path. In the equilibrium we construct, firm 1 uses its information to determine transfer payments between it and the other firms. In period t , firm 1 makes a payment to firm j of

$$f_j(m_j) \equiv E_{\varepsilon_t} [\pi_j(s^*, \varepsilon_t)] - \hat{\pi}_j(s_j^*, m_j).$$

Expected transfers are zero, but if firm j 's profit is less than its expected value, then firm 1 makes a payment to firm j . If firm j 's profit is greater than its expected value, then $f_j(m_j)$ is negative and firm j makes a payment to firm 1. Thus, firm j 's per-period payoff is constant at $E_{\varepsilon_t} [\pi_j(s^*, \varepsilon_t)]$, and firm 1 absorbs all the uncertainty generated by the shock ε_t . If either firm fails to make the required payment, then in the next period firms begin a punishment phase in which firms choose their Nash equilibrium strategies. For the results below it is sufficient to assume that the punishment phase is infinitely long.

We show that there exists $\delta' < 1$ such that for all $\delta > \delta'$, these strategies form an equilibrium. First, note that each firm's strategy is feasible in that it depends only on variables that it can observe. Second, we show that firm 1 has no profitable deviation. To

see this, note that for any price, firm 1 prefers to make the payments required of it rather than trigger a punishment phase.

Lemma 1 *For δ sufficiently large, for any s_1 , for all j such that $f_j(m_j) > 0$, it is a best reply for firm 1 to make the transfer payment $f_j(m_j)$ to firm j .*

Proof. If firm 1's does not make its required payments, it saves $\sum_{j \neq i} \max\{f_j(m_j), 0\}$, which is bounded above by $\sum_{j \neq i} E_{\varepsilon_t} [\pi_j(s^*, \varepsilon_t)]$, but the punishment phase begins in the next period, so firm 1's loses $\frac{\delta}{1-\delta} E_{\varepsilon_t} [\pi_1(s^*, \varepsilon_t) - \pi_1(s^e, \varepsilon_t)]$ in the continuation game. Thus, for δ sufficiently close to 1, it is a best reply for firm 1 to make the payments. Q.E.D.

Using Lemma 1, we can complete the demonstration that firm 1 has no profitable deviation. By Lemma 1, it is sufficient to show that for any s_1 , firm 1's expected payoff in period t if it chooses s_1 and makes the required transfers is less than or equal to its expected payoff in period t if it chooses s_1^* and makes the required transfers.

Firm 1's expected payoff in period t if it chooses s_1 and makes the required transfers is bounded above by $\max_{s_1} E_{\varepsilon_t} \left[\pi_1(s_1, s_{-1}^*, \varepsilon_t) - \sum_{j \neq i} f_j(m_j(s_1, s_{-1}^*, \varepsilon_t)) \right]$. Using the definition of $f_j(m_j)$, we can rewrite this expression as

$$\begin{aligned} & \max_{s_1} E_{\varepsilon_t} \left[\pi_1(s_1, s_{-1}^*, \varepsilon_t) + \sum_{j \neq i} \hat{\pi}_j(s_j^*, m_j(s_1, s_{-1}^*, \varepsilon_t)) \right] - \sum_{j \neq i} E_{\varepsilon_t} [\pi_j(s^*, \varepsilon_t)] \\ &= \max_{s_1} E_{\varepsilon_t} \left[\pi_1(s_1, s_{-1}^*, \varepsilon_t) + \sum_{j \neq i} \pi_j(s_1, s_{-1}^*, \varepsilon_t) \right] - \sum_{j \neq i} E_{\varepsilon_t} [\pi_j(s^*, \varepsilon_t)] \\ &= \Pi(s^*) - \sum_{j \neq i} E_{\varepsilon_t} [\pi_j(s^*, \varepsilon_t)], \end{aligned}$$

which is equal to firm 1's expected payoff in period t if it does not deviate. Thus, a deviation from s_1^* is not profitable. The intuition is that the transfer payments fix the amount of the joint surplus captured by firms other than 1, so it is in firm 1's incentive to maximize that joint surplus.

Finally, to complete the proof that our strategies form an equilibrium, we must verify that firm $j \neq 1$ has no incentive to deviate. If firm j deviates by choosing a price different from s_j^* , this either does not affect firm j 's period t payoff, for example if ε_t is such that all firms sell zero, or is detected by firm 1 with probability one (by assumption) and so triggers the punishment phase. This implies that for δ sufficiently close to one, firm j prefers not to

deviate in this way. If firm j deviates by not making a required transfer to firm 1, then this is detected and triggers the punishment phase, so again, for δ sufficiently close to one, firm j prefers not to deviate.

Proposition 4 *If profitable deviations from s^* are detectable by firm 1, then for δ sufficiently large, there exists an explicitly collusive equilibrium with one-sided monitoring in which s^* is played in every period on the equilibrium path if and only if transfers are allowed.*

Proof. It remains to be shown that s^* cannot be supported without transfers. To see this, note that in the absence of transfers the logic of Proposition 1 applies: Suppose there is an equilibrium in which the firms choose s^* in all periods on the equilibrium path. Then for all $\varepsilon_t \in \Omega$, if firm j observes $(\pi_j(s^*, \varepsilon_t), m_j(s^*, \varepsilon_t))$, then firm j chooses strategy s_j^* in the next period. But then, firm 1 can profitably deviate and, using (1), not trigger a response by the other firms. Q.E.D.

In the equilibrium described above, one firm can observe profitable deviations by the others, which prevents the less informed firms from having an incentive to deviate. The required transfers prevent the more informed firm from having an incentive to deviate. As shown in Proposition 4, these transfers allow firms to sustain the overall joint-payoff maximizing strategies in equilibrium.

4.2 Complete monitoring

In the explicitly collusive equilibrium of the previous section, firms must regularly make transfers to each other. In this section, we show that increased information sharing between the firms allows them to maximize their joint payoff in every period in an explicitly collusive equilibrium without using transfers. Thus, increased information sharing eliminates the need for transfers.

In this section, we assume each firm can observe the market outcome of every other firm. We refer to this environment as one with complete monitoring. The timing in each period is as follows: (i) firms simultaneously choose strategies, (ii) each firm observes its own payoff and own market outcome and the market outcome of its rivals.

Proposition 5 *If profitable deviations from strategy profile s^* are detectable by all firms, then for δ sufficiently large, there exists an explicitly collusive equilibrium with complete*

monitoring and no transfers in which firms maximize their expected joint stage-game payoff in every period on the equilibrium path.

Proof. The proof is by construction. Let σ^* be the values of the detection statistics associated with s^* . Consider the following strategies: For firm i : If (i) $t = 0$ or (ii) $t > 0$ and for all $\tau < t$, $\sigma_i(s_{i\tau}, m_\tau) = \sigma_i^*$, then choose $s_{it} = s_i^*$; otherwise choose $s_{it} = s_i^e$. Since any profitable deviation by firm i is detected by the other firms, then by the usual arguments, for δ sufficiently close to 1, deviations are not profitable. Q.E.D.

Using Proposition 5, if profitable deviations from strategy profile s^* are detectable, then there exists an equilibrium of the infinitely repeated game in which the firms maximize their expected joint stage-game payoff in all periods. This contrasts with our results for tacit collusion. As firms move from the optimal tacitly collusive equilibrium to the optimal explicitly collusive equilibrium, firms not only eliminate the need for equilibrium-path punishment periods, but also potentially increase the stage-game payoffs relative to those of the non-punishment periods under tacit collusion. The result of Proposition 5 also differs from our results for the case of one-sided monitoring in that no transfers are needed, on or off the equilibrium path, to support the optimal collusive outcome.

If profitable deviations from strategy profile s^* are detectable by all firms, then for δ sufficiently large, in the price competition environment of Proposition 3, in the optimal explicitly collusive equilibrium with complete monitoring, expected prices and joint stage-game payoffs are higher in every period than in the optimal tacitly collusive trigger-strategy equilibrium.

These results show that when each firm can monitor the market outcome of the other, firms can achieve the optimal cartel outcome without the use of transfers.

In Section 5 we show that, although the equilibrium described above does not require transfers, if we extend the model to allow small idiosyncratic shocks to market outcomes, then transfers can play a useful role since transfers that compensate for deviations in the value of the detection statistic $\sigma_i(s_i, m)$ from its cooperative value σ_i^* can be used to eliminate profitable deviations.

4.3 Centralized monitoring

In this section, we allow the firms to communicate via a third party, which we refer to as the center. For example, an industry association or trade association might play the role of

the center. We assume that firms report their market outcomes to the center and that the center can detect deviations from truthful reporting. The center then makes a public report, observable by the firms. We refer to this environment as one with centralized monitoring.

Our assumption that the center can detect deviations from truthful reporting can be based on several things. For example, a trade association may have the ability to audit firms' reports, or an association might require firms to post bonds that are forfeit if they are caught not reporting truthfully. Or a trade association might be able to observe firms' market outcomes directly, for example through publicly available import/export statistics. See Section 2 for specific examples.

We assume that the center reports a summary statistic based on the reports of the firms. We show that it is sufficient for the center to report the total quantity sold by the firms.

The timing within each period is as follows: (i) firms simultaneously choose strategies, (ii) each firm observes its own payoff and own market outcome, (iii) firms (truthfully) report their market outcomes to the center, and (iv) the center makes a public report.

Proposition 6 *If profitable deviations from strategy profile s^* are detectable by all firms, then for δ sufficiently large, there exists an explicitly collusive equilibrium with centralized monitoring and no transfers in which firms maximize their expected joint stage-game payoff in every period on the equilibrium path.*

Proof. The proof follows trivially from the proof of Proposition 5 if the center reports the firms' market outcomes. Q.E.D.

For environments with price competition and multiplicative demand shocks, the center need only report the sum of the reported market outcomes. In this case, each firm can use the center's report to calculate its own market share, which is sufficient to detect deviations by its rival. With more than two firms, we assume it is a probability zero event that a profitable deviation by one firm affects the market shares of some, but not all, of its rivals.

Proposition 7 *In environments with price competition and multiplicative demand shocks (or additive demand shocks and equal shares), then for δ sufficiently large, there exists an explicitly collusive equilibrium with centralized monitoring and no transfers in which the center reports the total quantity sold and firms maximize their expected joint stage-game payoff in every period on the equilibrium path.*

Proposition 7 shows that the existence of a trade association that reports only the total production in the industry is sufficient to support strategies that maximize the firms' expected joint payoffs. See footnote 2 on the legality of such reports.

Although it may be legally permissible for a trade association to report data in aggregate form, Proposition 7 suggests that the fact that data is aggregated is not sufficient to prevent that information exchange from being an important facilitator of collusion.

We have focused on the case of all-inclusive cartels. If a cartel is not all-inclusive, in order for the trade association to play the same role as described above in facilitating collusion it must report production numbers in a sufficiently disaggregated way that the cartel members can calculate the total production of the cartel firms. Henry (1994, 86) describes a DOJ Business Review Letter from 1992 that suggests approval for a trade association to report aggregate statistics for "relevant peer groups," creating room for the "legal" reporting by a trade association of aggregate statistics for a non-all-inclusive cartel.

Exhibit No. 2173 of the TNEC (1941) *Hearings* on cartels gives a "List of industries involved in cases brought before the FTC and/or the courts over the last ten years in which the members of any industry employed a trade association or other common agency to deprive individual sellers of their freedom to determine their own output and/or the prices at which they may sell, or to exclude other sellers from the trade." In those same hearings, Clair Wilcox testifies (p.13316) that, "It would seem to me that the only way to obtain complete assurance that the merriment, diversion, and conversation of which Adam Smith speaks do not lead to the conspiracies or contrivances to raise prices, which he fears, would be to place an agent of the Federal Government in every trade association office to read all correspondence, memoranda and reports, attend all meetings, listen to all conversations, and participate in all the merriment and diversion, and issue periodic reports thereon to the Trade Commission or the Department of Justice or to some other agency of the Government."

5 Market share allocations

In this section we focus on our main application of price competition and discuss market share allocations in more detail. Market share allocations play an important role in many known cartels (see the Appendix for some examples). The fixing of market shares eliminates the incentive to cut prices since a deviating firm "is moving along a demand curve which is a fixed share of the industry demand, and hence has the same elasticity as the industry curve at every price" (Stigler, 1964, p.46).

In this section, we let $n = 2$, and we assume firms choose prices and that the quantity demanded from firm i in period t when prices are $s = (s_1, s_2)$ is $m_i(s, \varepsilon_t) = D_i(s)\varepsilon_t$, where $\varepsilon_t \geq 0$, with $E[\varepsilon_t] = 1$. We assume no capacity constraints,²⁴ but our results continue to hold if we allow firms to choose a sales cap as part of their strategy.²⁵

For homogeneous products, when firms choose the same price, assume that the share of demand captured by firm i , $\lambda_i(e)$, depends on the unobservable sales efforts of the firms, $e = (e_1, e_2)$. We assume sales effort is costly, and we assume $\lambda_i(e) \in (0, 1)$, $\lambda_1 + \lambda_2 = 1$, and $\lambda_i(0, 0) \equiv \lambda_i^*$. By allowing the case in which $\lambda_i(e)$ is a constant, we include the possibility that sales effort has no effect and that market shares are exogenously given when firms choose equal prices. Thus, in this application, a firm's strategy consists of a price and a level of sales effort.

As noted by Posner (1976, p.52),

“Setting the price above a seller's costs will induce him to expend resources on upgrading his output in the consumer's eyes so as to take sales away from his competitors and thereby engross a larger share of the profits generated by the higher than competitive price. ... Thus it may be necessary to agree to limit not only price competition but the important forms of nonprice competition as well, a difficult thing to do since there are so many ways in which sellers can vie for the buyer's patronage.”

In this application, deviations are detectable by letting $\sigma_i^* = \frac{D_i(s^*)}{D_1(s^*) + D_2(s^*)}$ and using market shares as the detection statistic,

$$\sigma_i(s_i, m) \equiv \begin{cases} \frac{m_i}{m_1 + m_2}, & \text{if } m_1 + m_2 > 0 \\ \sigma_i^*, & \text{otherwise.} \end{cases}$$

As suggested by Green and Porter (1984), because firms can rely on calculations of market shares to detect deviations, this environment reflects Stigler's (1964) ideas about the role of information sharing in supporting collusion.

Note that in this application, sales effort is wasteful. However, in a tacitly collusive equilibrium with homogeneous products there may be no equilibrium in which sales effort

²⁴As shown in Benoit and Krishna (1987), if firms choose their capacities prior to playing an infinitely repeated price setting game, then collusive equilibria involve excess capacity, and the most collusive equilibrium may involve a joint payoff for the firms that is less than what could be achieved by a monopolist.

²⁵Imposing a sales cap might allow a firm to limit how much price undercutting reduces its rivals' sales and so might reduce the probability of detection.

is zero. But in an explicitly collusive equilibrium with one-sided monitoring or complete monitoring, the sales effort can be held down to its efficient level of zero.

Using the detection statistic described above, explicit collusion with complete monitoring does not require transfers; however, if we extend the model to allow small idiosyncratic shocks to market outcomes, then transfers can play a useful role since transfers that compensate for deviations in the value of the detection statistic $\sigma_i(s_i, m)$ from its cooperative value σ_i^* can be used to eliminate profitable deviations.

For example, suppose that when firms choose s , market outcomes are $m_1(s, \varepsilon_t) + \xi$ and $m_2(s, \varepsilon_t) - \xi$, where ξ is a “small” shock with mean zero. We can view these shocks as exogenous shocks to the firms or as mistakes by the firm. As noted in Posner (1976, p.53),

“Even so, the cartel price might be undercut inadvertently, because of a computational mistake or a failure of communication either of the agreed price or of a change in it. Mistakes of this sort must be common when coordination is effected, as it must be in industries subject to the Sherman Act, by clandestine means. Yet competing sellers will not know that the ‘cheating’ was inadvertent, and may retaliate; in this way a mistake can easily trigger a general round of price cutting.”

Consider an explicitly collusive equilibrium with complete monitoring in which, after market outcomes \hat{m}_1 and \hat{m}_2 are observed, firm 1 makes a transfer to firm 2 of x , where $x \equiv \hat{\pi}_1(s_1^*, \hat{m}_1) - \hat{\pi}_1(s_1^*, \tilde{m}_1)$ and $\tilde{m}_1 \equiv \sigma_1^*(\hat{m}_1 + \hat{m}_2)$. In this case, letting $\tilde{m}_2 \equiv \sigma_2^*(\hat{m}_1 + \hat{m}_2)$,

$$\begin{aligned}
\pi_2(s_2^*, \hat{m}_2) + x &= \pi_2(s_2^*, \hat{m}_2) + p(s^*, \varepsilon_t)(\hat{m}_1 - \tilde{m}_1) \\
&= \pi_2(s_2^*, \hat{m}_2) + p(s^*, \varepsilon_t)(\hat{m}_1 - \sigma_1^*(\hat{m}_1 + \hat{m}_2)) \\
&= \pi_2(s_2^*, \hat{m}_2) + p(s^*, \varepsilon_t)(\hat{m}_1 - (1 - \sigma_2^*)(\hat{m}_1 + \hat{m}_2)) \\
&= \pi_2(s_2^*, \hat{m}_2) - p(s^*, \varepsilon_t)(\hat{m}_2 - \tilde{m}_2) \\
&= \pi_2(s_2^*, \tilde{m}_2).
\end{aligned}$$

Thus, this transfer payment fixes the firms’ payoffs at what they would be in the absence of the shock ξ . Given this, the outcome of the explicitly collusive equilibrium with complete monitoring described in Proposition 5 can still be sustained if firms make transfers. To see this, note that as long as ξ is sufficiently small and δ is sufficiently large, then for all market outcomes, each firm prefers to incur cost ξ to avoid triggering a punishment phase.

6 Discussion

In Section 2, we argue that once a cartel resolves the issue of monitoring, there are advantages to a market share allocation as a basis for suppressing interfirm rivalry. In Sections 3–5, we show that the effective monitoring of a market share allocation can be accomplished through the standard and legally accepted practices of a trade association.

In the paper, we focus on the ability of various cartel organizations to enhance the profit of cartel members through the suppression of within-cartel rivalry. In this concluding discussion, we consider cartel activities that go beyond the suppression of within-cartel rivalry. In a tacitly collusive equilibrium, where there is no interfirm communication, it could be difficult for firms to recognize and coordinate upon conduct beyond the suppression of interfirm rivalry. In contrast, the history of explicit cartels as analyzed in Heeb et al. (2006) suggests that colluding firms often coordinate efforts to engage in monopolization-like conduct and/or shift out the demand curve for the cartel members' products, causing the maximal expected joint stage-game payoff to increase.²⁶ As described in Jones (1922, pp.261–274), trade associations may coordinate activities typically associated with a dominant firm in order to disadvantage non-member firms, including: controlling channels of distribution, organizing boycotts, establishing blacklists or whitelists, cutting non-members' supply, interfering with non-members' labor supply or procurement of storage facilities, predatory pricing, malicious litigation, espionage, intimidation and coercion, and misuse of governmental agencies.²⁷ Although Jones' (1922) focus is on trade associations, the examples of activities he provides apply equally well to cartels, regardless of whether a trade association is involved. Examples of activities designed to shift demand for cartel members' products include promotional and informational campaigns.

With a market share allocation, if cartel members share in the cost of monopolization or demand-enhancing activities according to their market shares, their costs are then in proportion to their benefits. Because the benefits of such activities will often extend beyond a given set of customers or beyond a given region, it may be more difficult to align costs and benefits when a cartel uses a customer or geographic allocation. Thus, these kinds of profit-enhancing cartel activities may be encumbered by a customer or geographic allocation

²⁶The Department of Justice public statement described in footnote 14 states, "Another device is the creation of a fund among a small group to buy competing plants which are troublesome competitors. Upon acquisition, such plants are often shut down and dismantled. Thus, the socially desirable small independent operation is eliminated from the field of competition."

²⁷See Jones (1922, pp.261–274) for discussion, examples, and cites to cases related to each of these.

relative to a market share allocation.

As a cartel undertakes monopolization or demand-enhancing conduct, profits may increase beyond what is expected from the mere suppression of within-cartel rivalry. To the extent that the identification and implementation of profitable monopolization and demand-enhancing activities requires information sharing among the firms, the information sharing of explicit collusion, perhaps through an industry association, can facilitate this.

In the Vitamins Cartel, although the cartel used market share allocations to deter secret price cutting, the EC decision in Vitamins indicates that the cartel also used market share allocations to allocate the cost of investments that provided cartel-wide benefits.²⁸ In general, in the absence of collusion, there are many actions that a firm in a homogenous good oligopoly could take that would benefit the multiple firms in the industry, but that would not provide sufficient benefit to the individual firm taking the action to justify the cost.

In conclusion, the sequence of models in this paper produce the ascending price path that is typically associated with collusion.²⁹ Prices are lowest with non-cooperative play. Prices ascend with tacit collusion but do not reach the level attained with explicit collusion. Explicit collusion prices are higher, but they increase even further when we allow for monopolization and demand-enhancing activities by a cartel.

²⁸For an example from the Vitamins Cartel of an investment that provided industry-wide benefits and whose cost was shared among the cartel firms according to their market share allocations, see the EC decision in Vitamins at 287: “In 1993 the parties [Roche and BASF] realised that a U.S. producer [of vitamin B2], Coors, had a larger production capacity for vitamin B2 than they had estimated in 1991. In order to prevent Coors from disrupting their arrangements by the export of its production surplus, Roche and BASF agreed that the former would contract to purchase 155 tonnes of vitamin B2 (representing half of Coor’s capacity) in 1993. BASF in turn would purchase 43 tonnes from Roche: the burden was thus to be shared in the same 62:38 proportion as their quotas.”

In another example, the following quotation is Article XX of the International Merchant Bar Agreement, 1933: “The Management Committee shall, whenever it deems necessary, call upon groups for contributions proportional to their quotas, to provide for or participate in the general expenses or other funds disbursed in the common interest.” (Hexner, 1943, p.317)

As described in Stocking and Watkins (1991, p.160), the International Nitrogen Cartel collected payments from its members in proportion to their sales to compensate Belgian producers for restricting their output.

As described in Stocking and Watkins (1991, p.160), the International Nitrogen Cartel collected payments from its members in proportion to their sales to compensate Belgian producers for restricting their output.

Also described in Stocking and Watkins (1991, p.447), DuPont and ICI contributed in proportion to their shares in the cooperative arrangement Explosives Industries, Ltd. to the compensation made to Westfälische-Anhaltische Sprengstoff A. G. (Coswig) for restricting its exports.

²⁹Our model is a repeated game, but is not fully dynamic. In more dynamic environments, a cartel’s success may be measured by the extent to which it prevents, minimizes, or delays a decline in prices, rather than its effectiveness at increasing prices.

Appendix

We reviewed the twenty major industrial-product cartel decisions of the European Commission between 2000 and 2005. Table A.1 lists these twenty cases in order by the decision date.

Table A.1: European Commission major industrial product cartel decisions (2000–2005)

	Case name	Relevant products	Decision date	EC Journal citation	Location on the EU website
1	Amino Acids	Lysine	7-Jun-00	OJ L 152, 07/06/2001 p.24-72	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2001/l_152/l_15220010607en00240072.pdf
2	Soda-ash - Solvay, CFK	Soda-ash	13-Dec-00	OJ L 10, 15/01/2003 p.1-9	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_010/l_01020030115en00100032.pdf
3	Graphite electrodes	Graphite electrodes	18-Jul-01	OJ L 100, 16/04/2002 p.1-42	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2002/l_100/l_10020020416en00100042.pdf
4	Vitamins	Vitamins	21-Nov-01	OJ L 006, 10/01/2003 p.1-89	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_006/l_00620030110en00100089.pdf
5	Citric Acid	Citric Acid	5-Dec-01	OJ L 239, 06/09/2002 p.18-65	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2002/l_239/l_23920020906en00180065.pdf
6	Zinc phosphate	Zinc phosphate	11-Dec-01	OJ L 153, 20/06/2003 p.1-39	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_153/l_15320030620en00100039.pdf
7	Carbonless paper	Carbonless paper	20-Dec-01	OJ L 115, 21/04/2004 p.1-88	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2004/l_115/l_11520040421en00100088.pdf
8	Methionine	Methionine	2-Jul-02	OJ L 255, 08/10/2003 p.1-32	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_255/l_25520031008en00100032.pdf
9	Industrial and medical gases (amended EC decision)	Industrial and medical gases	24-Jul-02	OJ L 084, 01/04/2003 p.1-55	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_084/l_08420030401en00010055.pdf
			9-Apr-03	OJ L 123, 17/05/2003 p.49-50	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_123/l_12320030517en00490050.pdf
10	Methylglucamine	Methylglucamine	27-Nov-02	OJ L 038, 10/02/2004 p.18-46	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2004/l_038/l_03820040210en00180046.pdf
11	Plasterboard	Plasterboard	27-Nov-02	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/37152/en.pdf
12	Food flavour enhancers*	Nucleotides	17-Dec-02	OJ L 075, 12/03/2004 p.1-31	http://eur-lex.europa.eu/LexUriServ/site/en/oj/2004/l_075/l_07520040312en00100031.pdf
13	Specialty Graphite	Specialty graphite	17-Dec-02	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/37667/en.pdf
14	Sorbates	Sorbates	1-Oct-03	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/37370/en.pdf
15	Electrical and mechanical carbon and graphite products	Carbon brushes	3-Dec-03	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/38359/en.pdf
16	Organic peroxides	Organic peroxides	10-Dec-03	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/37857/en.pdf
17	Industrial tubes	Copper tubing	16-Dec-03	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/38240/en.pdf
18	Copper plumbing tubes	Copper tubing	3-Sep-04	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/38069/en.pdf
19	Choline Chloride	Choline Chloride	9-Dec-04	OJ L 190, 22/07/2005 p.22-26	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/37533/en.pdf
20	Rubber chemicals	Rubber chemicals	21-Dec-05	Not published in Official Journal	http://ec.europa.eu/comm/competition/antitrust/cases/decisions/38443/en.pdf

*Note that most documents related to this case require you to search for "floud [sic] flavour enhancers"

For each of these 20 cartel cases, we use the EC decision to classify the cartel's organization as involving one or more of a customer allocation, geographic allocation, market share agreement, or some other organization. These are shown in Table A.2. Also shown in Table A.2, we indicate whether the EC decision mentions the involvement of a trade association or other outside organization in the cartel's activities. Note that the write-ups of the EC decisions are idiosyncratic and do not purport to expose all information regarding a cartel's

organization. So the absence of mention of a trade association in an EC decision does not necessarily mean that none was involved in facilitating cartel activities.

The EC decision paragraphs listed in Table A.2 are reproduced in the online appendix associated with this paper.³⁰

Table A.2: Paragraph numbers associated with discussions in the EC decisions indicating features of cartel organization and a role for a trade association

Case name	Customer allocation	Geographic allocation	Market share agreement	Other	Trade association
Amino Acids			211	211 (output quotas)	100, 113, 122, 253
Carbonless paper			81	81 (output quotas)	83
Choline Chloride	99	64	64, 99		
Citric Acid			81		87, 100
Copper plumbing tubes	137	239 (home mkt)	210, 239, 350		240
Electrical and mechanical carbon and graphite products	128	131	128		82, 177
Food flavour enhancers	65, 68	172			
Graphite electrodes		50 (home mkt)	71		
Industrial and medical gases	101				105
Industrial tubes	2, 79, 106, 107		2, 79, 103, 104		2, 6, 113
Methionine				64 (target prices)	
Methylglucamine	46, 98		43, 46		
Organic peroxides			85		92
Plasterboard				429 (price increases)	
Rubber chemicals			66		
Soda-ash - Solvay			58		
Sorbates				281 (output quotas)	
Specialty Graphite			147		
Vitamins			2, 169		
Zinc phosphate	2, 68		2, 214		35, 69, 254

As shown in Table A.2, for nine of these cartels, a trade association (or a technical standards committee or “consulting firm”) is mentioned in the EC decision. The nine are Amino Acids, Carbonless Paper, Citric Acid, Copper Plumbing Tubes, Electrical and Mechanical Carbon and Graphite Products, Industrial and Medical Gases, Industrial Tubes, Organic Peroxides, and Zinc Phosphate. In some cases, the association is described as playing a

³⁰ Available at <http://faculty.fuqua.duke.edu/~marx/bio/papers/OnlineAppendixMS.pdf>.

role by providing information to cartel members, in others a “consulting firm” audits data provided by cartel members, and in others an association is mentioned as providing cover for gatherings of cartel members.

In eight of the nine cases mentioning a trade association (all except for Industrial and Medical Gases), a market share agreement was a key component of the cartel’s organization. Viewed another way, of the fifteen cases where a market share agreement was a component of the cartel’s organization, eight mention a role for a trade association.

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