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ABSTRACT

Cartels face three key challenges: agreeing on a collusive price and allocation of output, adhering to that agreement, and preventing entry. Although company executives may meet in smoke-filled rooms and fix prices, many economists believe that these same executives leave these meetings and pursue their own individual interests. To evaluate the challenges to cartel stability, we estimate a proportional hazards model over a sample of contemporary international cartels. An important innovation is our analysis of a new data set quantifying the range of sophisticated organizational mechanisms used by cartels. We find that organizational practices contribute significantly to cartel stability. In particular, cartels that used market allocation mechanisms were significantly less likely to break up than those that did not. Negative macroeconomic shocks shorten expected cartel duration. Financial distress of member firms also appears to have a negative impact on cartel duration, though sample size limits the precision of our estimates.

I. INTRODUCTION

"People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices," wrote Adam Smith over two hundred years ago (Smith 1850, p. 59). Modern economists, while acknowledging that firms attempt to collude now and then, have been skeptical that these attempts could have much effect on market outcomes. Without government assistance, cartels would dissolve quickly as each firm was seduced by the temptation to increase its output and chisel its price to increase its own individual profits (Stigler 1964). The cartel's action to restrict output below the individually rational profit-maximizing level gives each firm an incentive to increase output beyond the agreed-upon amount. In other words, company executives exit smoke-filled rooms where they have agreed to fix prices and instruct their sales force to undercut competitors. They turn their backs on their partners in crime and pursue their own individual interests, to the benefit of consumers.

In this paper we seek to better understand the determinants of cartel stability (or instability) using a sample of international cartels that have been convicted of price fixing over the last two decades. Our sample includes 72 private international cartels, all convicted since 1990 by either the United States or the European Union. Of these 72 prosecutions, 19 were prosecuted in both jurisdictions; 20 were U.S.-only cases and 33 were EU-only cases. Each of these cartels engaged in illegal price fixing or market division agreements, and each includes member firms from more than one country.[1]

Cartels face three key challenges: agreeing on a collusive price and allocation of output (with an implicit or explicit division of industry profits), preventing cheating, and preventing entry (or growth) by cartel outsiders. Despite rapid technological change in communications in the late twentieth century, cartels still rely heavily on direct, face-to-face meetings and negotiations in order to conquer these challenges, perhaps because trust is undermined not only by the incentive to cheat but also by the illegality of the activity.[2] Cartels use complex measures

[1] In some cases, the legally responsible firm is based in the same jurisdiction as its fellow conspirators but is a subsidiary of a foreign corporation. We have included such cases as international cartels.
[2] The relationship between cartel stability and trust is discussed in detail in Leslie (2004).

to control prices, various terms of sale and distribution, and, in some cases, investment in capacity and sharing of technology.

In order to address these challenges, cartels develop sophisticated monitoring, compensation, and punishment mechanisms. An important innovation in this paper is our analysis of a new data set quantifying the organizational techniques that these cartels used to stabilize themselves. Estimating a proportional hazards model, we find that, at least among those cartels that left sufficient records for prosecution, these various organizational practices contribute significantly to cartel stability. We also identify different causes of cartel breakdown and estimate a competing risks model to distinguish between those cartels that have responded to recent innovations in antitrust prosecution by applying for amnesty, and those that dissolve due to antitrust prosecutions triggered for other reasons or due to market forces.

Along with internal cartel organization, industrial organization literature identifies a number of other potential determinants of cartel stability. Building on the previous theoretical and empirical studies that highlight the importance of demand fluctuations on cartel stability, we test for the effect of demand fluctuations on cartel stability. We also test for the effects on cartel stability of fluctuations in firm impatience, proxied by the market interest rate and by measures of company financial distress.

The basic theory of cartel duration is laid out in the following section. We then turn in Section III to a description of the data and a categorization of cartel organization techniques, with illustrations drawn from a variety of contemporary international cartels. Sections IV and V present the empirical model and results, respectively.

II. THE THEORY OF CARTEL DURATION

In a market with identical price-setting firms, infinitely repeated interaction among these firms, and perfect information, collusion can be sustained if: [3]

$$\sum_{t=0}^{\infty} \delta^t \Pi^i(p_{i,t}^M, p_{-i,t}^M) \succ \Pi^i(p_{i,0}^D, p_{-i,0}^M) + \sum_{t=1}^{\infty} \delta^t \Pi^i(p_{i,t}^C, p_{-i,t}^C)$$

where

[3] The notation and presentation of the problem of cartel sustainability rely heavily on Tirole (1988), pp. 245-253.

$p_{i,t}^{M}$ is the collusive (monopoly) price charged by firm *i* in period *t*,

$p_{i,t}^{D}$ is the price charged by firm *i* if it chooses to defect from the collusive agreement,

$p_{i,t}^{C}$ is the price charged by firm *i* in the continuation equilibrium following a defection by one firm,

Π^{i} is the profit earned by firm *i* in a single period, and

δ^{t} is the discount factor in period *t*, with $\delta^{t} = e^{-r\tau}$ where *r* is the instantaneous rate of interest, and τ is the real time between periods.

This inequality, known as the participation constraint, says that permanent collusion can be an equilibrium if firms are sufficiently patient and if the difference between the profits earned while colluding and the profits earned after a firm cheats is sufficiently high. A simple interpretation of this model would suggest that we observe two types of markets: those for which the participation constraint is not met and in which therefore competitive conditions necessarily obtain, and those for which this constraint is met and in which collusion may therefore obtain forever.

What can this model tell us about how long an existing cartel will *last*? What factors might lead to an existing cartel's demise? Some theories of cartel behavior have tried to answer this question by considering equilibria in which collusion does last, but in which firm behavior fluctuates.[4] These fluctuations in behavior are often observationally equivalent to cartel breakup. In the discussion that follows, we consider hypotheses regarding the determinants of cartel duration that follow from these equilibrium models with behavioral fluctuations.

We also consider the possibility that, while firms expect this inequality to hold when a cartel is formed, the constraint is violated by future, unanticipated shocks.[5] In that case, duration would be systematically related to the unanticipated shocks that lead to the violation of the participation constraint. This framework motivates our specification of the determinants of cartel duration by focusing the analysis on identifying the kinds of shocks that might disrupt

[4] Green and Porter (1984) and Porter (1983) introduced the notion of price wars as equilibrium punishments in which it appears that collusion has broken down, but where in fact the cartel shifts to a "punishment phase" that is required to maintain incentive compatibility.

collusion. Our research suggests that cartels that endure do so because they develop organizational techniques that are effective shock absorbers, allowing them to weather external shocks. In our empirical model, we measure both the external shocks that may disrupt collusion, and the organizational techniques cartels have employed to *prevent* such shocks from disrupting collusion. In the discussion to follow, we identify the broad factors that may determine how long cartels will last, and lay out the hypotheses to be tested in the empirical model.

A. Firm Patience and Collusive Stability

One of the few generalizations that can be made from the repeated game model of collusion is that collusive stability is inversely related to the discount rate: firms that heavily discount future profits cannot be induced to restrict output in the current period. If the discount rate, δ^t, fluctuates over time, prices that can be supported as a collusive equilibrium at the prevailing discount rate may no longer be supportable if the discount rate falls below some critical level.

The most obvious source of fluctuation in the discount rate is fluctuation in the market interest rate. Thus, an unanticipated increase in the market interest rate may destabilize an ongoing collusive equilibrium. Firm-level changes might also affect the impatience of an individual member of a cartel. For example, the time preference of a privately held firm may depend on the age profile of large stockholders. A firm's time preference might also change if its financing changed to depend more heavily on debt relative to equity. The increased reliance on debt requires fixed payments to lenders, reducing a firm's discretion and increasing its need for cash flow in the short run.[6] Lengthening the time between periods of competition also increases the discount rate. While the time between periods is less likely to fluctuate frequently, reducing the real time between periods will weaken the constraint on collusive equilibria and make collusion less fragile. Thus, we expect colluding firms to try to enact changes in business norms, when feasible, that would shorten the length of time between decision-making periods. For example, cartels might agree to eliminate long-term contracts or the extension of credit to customers.

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[5] Harrington (2006) is, as far as we know, the only formal exposition of such a model. The intuition of his model is very similar to the argument we make here.

[6] For a broader discussion of the relationship between free cash flow and managerial decisions, see Jensen (1986).

B. Imperfect Information and Collusive Stability

In some theoretical specifications, collusion essentially ends after some specified history of industry interaction because the "punishment" following that history is a permanent or long-term reversion to competitive pricing. In these specifications (for example, Green and Porter, 1984), imperfect information makes it impossible for firms to infer with certainty that other firms are cooperating. If, for example, firms only observe their own sales, $x_{it}(p_{it}, p_{-i,t}, \theta)$, where θ is a random shock to demand, firms may be unable to distinguish between $x_{it}(p_{i,t}^{M}, p_{-i,t}^{C}, \theta_H)$ and $x_{it}(p_{i,t}^{M}, p_{-i,t}^{M}, \theta_L)$ where θ_H indicates a high realization of demand and θ_L indicates a low realization of demand. In such a market it is possible that we could observe collusive behavior followed by competitive behavior because a low realization of demand (θ_L) occurs which firms are unable to distinguish from low pricing by a competitor.

The reliance on punishments—or the threat of punishments—to sustain collusion has two primary implications for cartel duration. First, cartels are more likely to survive in industries where information is better and cartel participants can distinguish between cheating and demand fluctuations. Markets with high variability in demand are more likely to have a realization of unexpectedly low demand than relatively stable markets. Thus we expect that demand variability, especially demand variability that cannot be predicted by well-informed market participants, is likely to shorten cartel duration.

Second, because the abandonment of collusion and the enactment of an "equilibrium punishment" of permanent or long-term reversion to competitive pricing are costly to firms in terms of foregone future profits, firms try to avoid making mistakes in enacting punishments. Cartels know that there will be some variation in demand that may cause individual firm's sales or market shares to differ from what the cartel planned. Cartels *plan* for this variation in demand by using agreed-upon compensation schemes. In many cases, cartel members that sold more than expected must buy output from cartel members that sold less; this, of course, lessens a cartel member's incentive to cheat and sell more than its quota. In other cases, firms provide compensation by allowing their competitors to sell in their designated markets, or they provide direct monetary compensation. While these mechanisms for dealing with variation in market outcomes reduce the incentive to cheat, they might raise the risk of detection by competition authorities. We expect that cartels that develop such compensation mechanisms to deal with

deviations in cartel member behavior will endure longer, all else equal. Conversely, we expect that legal environments which make the use of compensation schemes more difficult will decrease cartel duration.

Recognizing the complications brought about by imperfect information, cartels often put substantial effort into monitoring one another's activities in order to increase observability, so that they *can* distinguish between the events resulting from demand variability and changes in competitors' prices. Many cartels exchange output, sales, and price data with each other, or forward data to a third party, such as a trade association or an independent auditor. In other cases, cartel members will agree to use a single distributor (such as a joint sales agent) or will bring one or more distributors into the cartel. Engaging the cooperation of a distributor is likely to improve the information that the cartel has regarding fluctuations in demand. A single distributor can literally prevent firms from cheating, at least in the short run, because the producing firms have no facilities to deliver product to customers and no direct contact with customers.

One of the simplest and most common techniques that cartels use to reduce imperfect information and monitoring problems is to assign markets to individual producers. In some cases, individual consumers are allocated to individual producers so that only one cartel member is permitted to sell to a particular customer. In other cases, regions or countries are assigned to individual producers. Assigning countries to individual producers has the advantage that the cartel can monitor public information on imports and exports between countries to assure that no cartel members are violating the market division agreements.[7]

Finally, cartels often find that having agreed on price, cartel participants try to compete in other dimensions, such as the provision of credit, transportation, or the quality of the product. These other dimensions of competition may be more difficult to observe and monitor than price. Competition along non-price dimensions, however, erodes collusive profits in a manner parallel to chiseling on price. Therefore, some cartels explicitly limit competition on such non-price dimensions.

[7] This does not work in all cases, but it can work if there is only one producer in a given country. We present an example below in which a cartel used export statistics to monitor adherence to the agreement.

C. Buyer and Seller Concentration

If there are *n* symmetric firms and they use a symmetric sharing rule, such as $\Pi^i = 1/n \sum_{i=1}^{n} \Pi^M$, then the returns to collusion for any individual firm will be decreasing in the number of firms. On the other hand, the returns to defection are unlikely to be affected by the number of firms in the market. Thus, the collusive participation constraint is more likely to be binding in industries with more firms and lower concentration. Shocks that affect industry profitability are more likely to disrupt collusion in un-concentrated industries than in concentrated ones. It is also likely that the observability of cheating (distinguishing between θ_L and $p^C_{-i,t}$) is more difficult with a large number of firms. Thus, for a variety of reasons we expect cartel duration to be positively related to concentration in the cartelized industry and negatively related to the number of participants in the cartel.

For analogous reasons, new entry into the industry, even if the entrant is welcomed into the cartel, will reduce the profitability of collusion and possibly undermine cartel stability. Conversely, barriers to entry are expected to increase cartel duration. Cartels will sometimes engage in strategic activities, such as patent pooling, standard setting, or petitioning for anti-dumping protection, that are designed to increase barriers to entry.

Turning to the buyer side of the market, theory suggests that buyer size can affect cartel stability. If the customers of a cartel are large relative to the size of the market, the temptation to cheat may be greater because each firm will find it easier to "steal" a large proportion of the market from other firms (Stigler 1964). In this case, the short-term profits from deviating from the collusive equilibrium, $\Pi^i(p^D_{i,t}, p^M_{-i,t})$, may be close to the entire monopoly profit for the industry (for one period). The larger are the cartel's customers relative to the size of the market, the easier it will be for a single firm offering customers $p^D_{i,t} = p^M_{i,t} - \varepsilon$, to capture the entire market. Highly concentrated downstream industries imply a small number of (relatively large) buyers for the upstream industry. Thus, we expect cartel duration to be negatively related to the concentration of the downstream consuming industry.

D. Antitrust Policy and Cartel Duration

In the last ten years, there has been a major transformation in the attitude of competition authorities toward international cartels. In the past, the most hostile antitrust authorities still presumed that international cartels were largely beyond prosecution – either for reasons of jurisdiction, difficulties in gaining evidence, or the diplomatic issues raised. Today, the United States, the European Union, Canada, Australia, South Korea, and other countries are willing, perhaps even eager, to take on international cartels. It is this increased prosecution that has permitted the creation of the data set analyzed here: every one of the international cartels in our sample was found to have violated competition laws in the United States or Europe.

Roughly eighty percent of the cartels in the sample ended because of antitrust intervention. This might suggest that our empirical investigation should focus on the determinants of enforcement and detection, rather than the economic forces that might undermine cartel stability. However, the key enforcement instrument used by competition authorities since the mid-1990s in uncovering international cartels has been the offer of amnesty or leniency to the first firm that cooperates with the competition authorities by providing evidence of collusion. These amnesty and leniency policies (which we discuss in detail below) alter a firm's decision to participate in a cartel.

In a world of *perfect information*, a firm that chooses to deviate from the cartel agreement will—knowing that its defection would induce a reversion to competition in the industry—simultaneously apply for amnesty. In this case, the decision process regarding defection is not altered. Any shock that would cause a previously colluding firm to defect from the cartel would also cause that firm to report the cartel to the antitrust authorities. Thus, when we observe that a cartel has been broken up by an amnesty application followed by antitrust enforcement, we should also observe some shock that would lead the previously cooperating firm to defect. In some cases, the shock is quite obvious, as when a new owner takes over the firm, discovers the illegal activity, and immediately announces that the firm is withdrawing from the cartel and applying for amnesty. In such a case there is a change in either the firm's rate of time preference or its general preferences that leads to a violation of the participation constraint. The observation that the antitrust authorities take an action which ultimately puts an end to the cartel does not

vitiate the economic analysis; the antitrust authorities become the instrument of the defecting firm.

In a world of *imperfect information*, firms will consider the impact of their output decisions—to cheat or not—on the likelihood that the industry will revert to competitive conditions. A firm considering a small, profit-increasing deviation would know that such a deviation increases the probability (but not the certainty) of retaliation by the rest of the cartel. Prior to the adoption of amnesty policies, the worst credible punishment that a cartel could threaten to implement was permanent reversion to a competitive equilibrium (either Bertrand or Cournot, depending on the market). But the existence of an amnesty policy creates a more a severe, but still credible, punishment instrument, namely competitive reversion combined with antitrust prosecution. In this case, the cheating firm is punished by a fellow cartel member who both lowers price and goes to the antitrust authorities, which will result in fines and perhaps jail sentences for convicted firms and their executives. The possibility of a more severe punishment increases the size of the set of collusive equilibria and the potential collusive profits available to a cartel, making collusion easier and presumably therefore more durable. Thus, it is theoretically possible that these policies decrease the likelihood of cartel breakup. In those cases where we do see cartels broken up by an amnesty application, it is possible that the amnesty application is associated with an economic shock that led a firm to choose to deviate (as in the world of perfect information) or that we are observing the implementation of an equilibrium punishment. While the policy implications differ, the empirical prediction is the same: shocks that may vitiate or tighten the participation constraint may cause cartel breakup, even breakups initiated by amnesty applications.

Consider now a cartel formed under the earlier antitrust regime, in which firms heavily discounted the possibility of antitrust prosecution. An individual cartel member firm, and each of its managers, must consider both the option of defecting and applying for amnesty and the possibility of its competitors doing so. Suppose there is uncertainty on the part of cartel members about whether all firms will continue to cooperate. This could arise because there is uncertainty about a competitor's "type" or because there is asymmetry among the firms, so that some firms are closer to the tipping point implied by the participation constraint expressed above. Then the introduction of an amnesty or leniency policy might lead a cartel participant to apply for amnesty rather than face the risk of large fines or jail sentences. It seems likely that

firms that apply for amnesty are those close to the tipping point or those that fear that a co-conspirator is close to the tipping point. Thus, cartels that are broken up by amnesty applications are likely to be more fragile and shorter-lived cartels than those not broken up by amnesty, even if there were no amnesty policy. Therefore, although amnesty policies shorten cartel life, they do so disproportionately for cartels that had little effect on profits and were likely to be short-lived in any case. Again, the implication for antitrust policy is perhaps a more skeptical approach to amnesty, but the empirical prediction does not change. Amnesty applications should be affected by the same economic shocks that lead cartels to break up on their own accord.

III. DATA

A. Sample of Contemporary International Cartels

We consider these issues by examining a sample of 81 private international cartels existing in 1990 or later, convicted of price-fixing or market division in either the United States or the European Union (or both).[8] The cartels in our sample date from 1971 to 2002.[9] A cartel meets our selection criteria if the participants come from multiple countries.[10] Although these cartels are international in membership, they may or may not have a global reach. Many of the cartels attempted to set prices worldwide, while others confined their activities to one country, such as the United States, or one region, such as Western Europe. Under current law, virtually all such agreements are illegal in these two jurisdictions.[11] For 72 of these cartels, we have been able to assemble information on the characteristics of the market (such as number of firms and industry concentration), characteristics of the cartel, and the cause of cartel breakup.

[8] We do not include state-run cartels in the analysis. State-run cartels, such as OPEC, can have an important impact on economic activity, but their goals are more complex than private cartels, including not only the maximization of joint profits, but national economic stability and international political influence as well. The cartel monitoring and enforcement tools at the disposal of state-run cartels differ from those available to private firms. The economic models that we discuss here presume a simple profit-maximizing objective function, and are therefore inadequate to address the distinct features of state-run cartels.

[9] That is, one cartel of the 72 cartels in our sample—the organic peroxides cartel—began in 1971. There are two cartels, chemical tankers and memory chips, which both ended in 2002.

[10] We use the nationality of the parent company to identify a country of origin for each cartel member. For example, if a U.S. subsidiary of a Japanese company is prosecuted for price-fixing, we consider this to be a Japanese company.

[11] There are exceptions for certain industries and also for joint export associations. In the U.S., export associations are given limited antitrust immunity under the Export Trading Company Act (1982). In the European Union, countries restrict their competition legislation to the domestic market, with no mention of behavior affecting foreign markets.

Cartels affect a remarkably broad range of industrial sectors. Our international cartel sample includes firms primarily in sophisticated intermediate manufactured goods and services—from commodities like citric acid and methionine (an amino acid used in animal feed), to specialized services such as fine arts auctions and wastewater treatment facility construction. Chemical products top the list with 42 percent of the sample, as shown in Table 1. The next largest product category is water transportation, including ocean shipping, various ferrying operations, and a variety of specialized oil and chemical transport (14 percent of the cartels in our sample). Other manufacturing makes up most of the rest of our sample (38 percent) with multiple cartel convictions in steel, carbon and graphite products, plastics, and paper industries as well as a smattering of other products, such as beer, haberdashery goods, cartonboard, and tobacco processing. The only categories of products that do not appear in this sample are final retail goods and services.

The distribution of cartel duration in this sample is skewed with a long right hand tail (Figure 1). A non-parametric estimate of the Kaplan-Meier (KM) survivor function, the probability of survival past time *t*, is shown in Figure 2. The estimated probability of survival declines quite sharply in the first five years of a cartel's life, and then flattens out, so that cartels that survive past five years have a reasonable probability of lasting a very long time. There were long-lived cartels, for example, in sorbates, stamp auctions (where a U.S. and European bidding ring operated for at least two decades), and organic peroxides. At the other extreme, fewer than ten percent of the cartels in our sample lasted two years or less. One such cartel is the cross-Channel ferry operators' cartel, which was ended by a complaint from the Freight Transport Association representing British exporters.[12]

The average duration of cartels in our sample was approximately 7.5 years, with a standard deviation of 5.4 years (Table 2). The median lifespan was 6 years. As shown in Table 2, the duration of explicit price-fixing conspiracies in other international samples is comparable. Suslow (2005) examines 71 international cartels active before World War II and finds an average duration of 8.3 years.[13] Eckbo (1976) examines a sample of 52 international cartels spanning most of the 19th and the first half of the 20th centuries, and he finds an average duration of 5.3

[12] Adrian Strain, "Ferry Giants Hit Back at Price-Fix Charges." *The Evening Standard*, March 7, 1995.

years. Griffin (1989) examines 54 international cartels between 1888 and 1984 and finds an average cartel lifespan of 7.3 years. The U.S. comparison is similar, with Posner (1970) and Gallo et al. (2000) finding that the average duration of cartels prosecuted by the U.S. government was 7.5 and 5.4 years, respectively. In studies including a measure of variance, the variance in cartel duration is high.[14] As Stigler (1964) argued, there are cartels that dissolve quickly: each of these national and international samples includes cartels that barely lasted one year. There are other cartels that endure nonetheless, and average cartel duration does not appear to have changed substantially over the past century.

Most of the cartels in our sample consisted of a small number of firms. The median number of firms in our sample of cartels is 5, and the mean is 6.7. The number of firms ranges from two (including two vitamins cartels dominated by Hoffman-LaRoche and BASF) to a shipping cartel with thirty-five members. The existence of some cartels with a large number of participants is not as paradoxical as it may seem. Of the twelve cartels that had more than ten members, ten relied on the active involvement of a trade association (discussed further below). To get a sense of the data, Figure 3 shows the KM survivor functions where the data are segmented on whether the cartel had more than five firms. Cartels with fewer members appear to last longer than cartels with more members. However, it is likely that cartels with fewer members are also cartels in more concentrated industries, since these cartels generally included all, or virtually all, industry participants. Because we expect cartels in more concentrated industries to be longer lived, we attempt to disentangle these two effects in the multivariate analysis below.

International cartels occur predominantly in very highly concentrated industries. The average four-firm concentration ratio (C4) for our sample is 79 percent, based on a sub-sample of 48 cartels for which we can gather market share data. Three-quarters of the cartels were in industries with C4 of over 75 percent or a Herfindahl-Hirschman index (HHI) of over 1800, the threshold for "highly concentrated" industries in U.S. merger review.[15] We observe even more

[13] The mean duration of all cartel episodes in Suslow's sample is 8.3 years (standard deviation of 6.2 years). The mean duration of those cartels not censored by the start of World War II (28 of the 71 cartels) was 3.7 years (standard deviation of 3 years).

[14] The standard deviation of cartel duration ranges from 2.4 years in Eckbo's study (a sub-sample for which he is able to measure duration), to 6.3 years in Griffin's study.

[15] U.S. Department of Justice and Federal Trade Commission, Horizontal Merger Guidelines (1992, revised 1997), *available at* http://www.ftc.gov/bc/docs/horizmer.htm.

extreme concentration levels for many cases: of the 48 cartels for which we were able to obtain some measure of industry concentration, 17 operated in industries with a C4 of at least 90 percent.[16]

We have not identified any other studies of international cartels that were able to measure industry concentration systematically.[17] Instead, many empirical studies of international cartels measure the *cartel's* market share. These are generally studies of legal, public cartels, which may permit the creation of a formal collusive organization at lower industry concentration levels. For example, Griffin (1989) reports the cartel's market share for a sample of fifty-four international cartels: 35 percent of the cartels in his sample have market shares of at least 75 percent, and 17 percent (9 cartels) have market shares of at least 90 percent. Suslow (2005) reports that for 39 of the 71 cartels in her sample where she was able to gather cartel market share data, the average cartel had at least fifty percent of the market.[18] In almost all cases in our sample, the cartels included all of the major firms, so that our measure of industry concentration is close, although not identical, to the cartel market share. Thus, it seems as though cartel market share is much higher in our sample than has been found in previous samples of international cartels from an earlier era.

One might expect that it would be easy to establish that cartels are most common in highly concentrated industries, but the empirical relationship is more complicated.[19] This is partly because concentration is endogenous. Especially where collusion is legal, cartels may allow more firms to remain in the industry than would be sustainable in a more competitive environment (Sutton 1991, 1998, and Symeonidis 2002). One might also expect that explicit conspiracies to fix prices would be unnecessarily redundant for firms in highly concentrated industries. The high concentration ratios in our sample may therefore reflect our selection criteria, since we are sampling cases of firms who got caught. Firms in highly concentrated

[16] The vast majority of these concentration ratios are for the global market, but there are a few pertaining only to the U.S. market if that was the only country in which the cartel tried to fix prices.
[17] In a paper on U.S. price-fixing cases, Hay and Kelley (1974, pp. 22-23) report estimates of industry concentration that are roughly comparable to what we find: "In thirty-eight of fifty cases for which estimates could be made the concentration ratio was greater than 50 percent."
[18] Suslow (2005, p. 12) reports a median value of 1.4 for a dummy variable defined to be 0 if the cartel's market share was below 50%, 1 if it was between 50% and 75%, and 2 if it was greater than 75%.
[19] See Levenstein and Suslow (2006, pp. 57-61) for further discussion of previous findings on the relationship between concentration and the likelihood of collusion.

industries with keener leadership may be able to find ways to avoid competition without resorting to collusion – and the threat of prosecution.

In some cases, existing concentration ratios reflect the actions that cartels have taken to limit entry into their markets. About one-fourth of the cartels in our sample engaged in some type of exclusionary tactics. For example, both the steel beam and graphite electrode cartels were accused of restricting the flow of technical information to outsiders to prevent the production process learning necessary to compete in global markets.[20] In several other cases, cartels were found to have engaged in what one might consider predatory pricing to force rivals out of the market. For example, in 1992 members of the electrical carbon cartel reacted to an East German competitor that had entered the market after 1990 unification by refusing to supply any graphite to the entrant and by "systematically undercutting it with all customers, so that it would not be able to sell anywhere."[21] Similarly, citric acid producers "tried to regain some of the customers lost to the Chinese suppliers through concerted and carefully targeted price war."[22] The most direct form of market exclusion is the acquisition of competitors. In actions reminiscent of John D. Rockefeller and Standard Oil, the organic peroxide producers "agreed that each of them would purchase such a (new) competitor. Akzo agreed to acquire the organic peroxide business of Nobel and Enichem. Laporte would purchase Aztec. Atochem would take over [...]. Only the latter did not occur."[23]

B. Organizational Characteristics

In many instances, the theoretical model of collusion suggests a determinant of cartel duration that is influenced both by a variable which is clearly exogenous to the cartel and by the activity of the cartel itself. For example, market concentration is influenced both by the extent of economies of scale and by the decision of cartel members to acquire new competitors. In each of these cases, we have attempted to obtain a reasonable proxy for the exogenous determinant of

[20] For the steel beam cartel, see Charles Goldsmith and Martin du Bois, "European Commission Fines Steelmakers $116.7 Million," *Wall Street Journal Europe*, February 17, 1994, p.3. For graphite electrodes, see "Japanese Subsidiary Charged with International Conspiracy to Fix Prices for Graphite Electrodes in U.S." Department of Justice press release, February 23, 1998 (where one of the charges listed is that the conspirators "agreed to restrict non-conspirator companies' access to certain graphite electrode manufacturing technology").
[21] Commission Decision of 3 December 2003, Case C.38.359- Electrical and Mechanical Carbon and Graphite Products, par. 157.
[22] European Commission Press Release, "Commission Fines Five Companies in Citric Acid Cartel," December 5, 2001.
[23] Commission Decision of 10 December 2003, Case COMP/E-2/37.857-Organic Peroxides, par. 271.

cartel stability and to determine what, if any, activities the cartel itself engaged in that would affect cartel stability.

MacKie-Mason and Pindyck (1987), examine the mercury cartel and argue that structural factors, such as barriers to entry, are much more important that organizational ones. In the absence of barriers to entry, organizational innovations were able to preserve the formal structure of the cartel, but not its ability to increase price. In contrast, a study of the sugar industry by Genesove and Mullin (2001) concludes that organizational learning and innovation were critical to the cartel. Previous cross-sectional studies have qualitatively characterized the various mechanisms that cartels use to create barriers to entry and prevent cheating, but have had little success in establishing a systematic relationship between organizational variables and collusive success. In part, this is because cartels differ in their ability to develop and implement sophisticated cartel organizations as a result of differences in the history of interaction among industry participants that affect the level of trust in the industry, differences in their knowledge and experience regarding the organization and implementation of cartel agreements, and differences in the personalities of managers involved.[24]

Table 3 provides a summary of the organizational mechanisms employed by our sample of contemporary international cartels, and compares it to several studies of U.S. price-fixing cases. Over eighty percent of the cartels in our sample allocated geographic markets or assigned specific customers to cartel members. There are two main explanations for this. First, national barriers provide a ready mechanism for dividing markets and monitoring cartel adherence to the agreement.[25] For example, Hoffman-LaRoche, the world's leading producer of vitamin B2, monitored Japanese government export data knowing that there was only one cartel member, Takeda, producing in that geographic location.[26] National boundaries also provide focal points and institutionally-supported market divisions (supported by differences in language, currency, and distribution networks) that can facilitate collusion. Thus, removing trade barriers across

[24] Spar (1994), focuses on how prior interactions among firms influence expectations and therefore the set of feasible equilibria. She concludes that cartels are "best managed by those producers who are able to keep the circle of negotiators small, the rules flexible, and the power to retaliate as strong as possible" (p. 219). Baker and Faulkner (1993) argue that organizational issues were critical to the success of the electrical equipment conspiracies of the 1950s.

[25] This has been true of international cartels in the past: See Liefmann (1927, pp. 130-131), describing how international cartels allocate markets geographically. Suslow (2005, p. 12) reports that 40 percent of her sample of inter-war international cartels assigned exclusive territories to cartel participants.

[26] Commission Decision of 21 November 2001, Case COMP/E-1/37.512 - Vitamins, par. 289.

national boundaries may not give rise to competition as readily as has been expected, especially in highly globally-concentrated industries. Second, it is possible that the use of market allocation mechanisms reflects increasing sophistication of cartels as firms gain experience with collusive devices. While cartels often begin with simple agreements over price, the participants regularly find that collusion only succeeds when those agreements are bolstered by other mechanisms to limit competition.

In some markets, customers or market shares are assigned by engineering the rotation of bids among cartel participants. Bid rigging requires more coordination and more specific mechanisms for hiding collusion than other types of collusion, but also sometimes—particularly in the case of governmental customers—provides public information that cartel participants can use to monitor cooperation. Bid rigging often requires additional mechanisms for compensating the "losing" bidders. For example, members of a cartel fixing the price of postage stamps "carried out the bid-rigging schemes by participating in secret pre-auctions to determine which stamp dealer would be the bidder for specific lots of stamps at the subsequent public auction … and by making payments to stamp dealers who agreed not to bid at public auctions when they were not the high bidder at the pre-auction."[27]

Joint distribution agreements are the strongest form of market allocation that cartels use. Historically, cartels often turned to joint distributors who would simply eliminate cheating by having all sales funneled through a single central sales organization. In today's legal environment, such an obvious mechanism for eliminating competition would quickly attract the attention of antitrust authorities. Not surprisingly, we do not observe the use of joint sales agencies in our sample. However, in 14 percent the cartels in our sample (Table 3) we see active cartel participation by distributors, whether independent firms or producer-owned.

Cartel adaptability is reflected as well in the 47 percent of cartels that agreed to limit competition on dimensions other than price. These agreements often restricted the offering of discounts, the provision of credit, or the absorption of transportation costs. In other cases, the agreements went further, restricting advertising and point-of-sale promotions, as members of the

[27] Department of Justice press release "California stamp dealer charged with rigging auctions," June 26, 2002. See Kwoka (1997) for another example of a bid-rigging cartel using a post-auction redistribution mechanism.

beer cartel agreed to do, or restricting interest free loans, charitable donations, and advances paid to sellers, as agreed to by members of the fine arts cartel.[28]

A smaller proportion of cartels (six percent) adopted agreements standardizing the product itself. For example, the isostatic graphite cartel "agreed... to standardize the grades of non-machined and semi-machined isostatic graphite offered to customers in the United States and elsewhere for the purpose of facilitating the implementation of the … agreement…"[29] The pre-insulated steel heating pipe cartel "used quality norms [enforced by the trade association] to keep up prices and delay the introduction of new cost-saving technology."[30] These provisions limit the other dimensions on which member firms might chisel price. Recent research on semi-collusion has established that agreements that restrict competition on price but not other dimensions of competition can actually leave the colluding firms worse off than if they had not colluded at all (for example, Feuerstein and Gersbach 2003). Cartel participants prevent (or try to prevent) such outcomes by developing more complete agreements that cover all significant dimensions of competition.

As discussed above, preventing cheating is one of the central challenges cartels face. Cartels have developed a variety of mechanisms to address this challenge: 1) schemes to increase the information that firms have about one another and the market; 2) schemes to compensate one another when firms' sales vary from assigned quotas due to factors outside of their control, such as random fluctuations in demand; and, 3) schemes to punish firms when violations do occur. We address each of these mechanisms—monitoring, compensation, and punishment—in turn.

Almost three-quarters of the cartels in our sample exchanged information on sales, production, and price in order to monitor individual firm behavior and market trends (Table 3). In some cases, cartel members monitored one another directly. For example, the industrial copper tubes cartel fixed target prices at meetings each autumn. Then, "[i]n the spring meeting they monitored compliance with the agreed targets by analyzing the general market information

[28] Commission Decision of 5 December 2001, Case IV/37.614/F3 PO (Interbrew and Alken-Maes), par. 44, 47; "Sotheby's and Former Top Executive Agree to Plead Guilty To Price Fixing On Commissions Charged to Sellers At Auctions," Department of Justice press release, October 5, 2000; and "Commission rules against collusive behavior of Christie's and Sotheby's," European Commission press release, Oct. 30, 2002.
[29] United States of America v. Carbone of America Industries Corp. and Michel Coniglio; Criminal No. 00-129, March 13, 2000, p. 5.

and the development of their market shares.... [Cartel members appointed] market leaders who monitored customer visits and informed the other cartel members of the evolution of the contract situation within their respective territories."[31] The vitamin A and E cartels had some of the most sophisticated monitoring mechanisms we observe. The "BASF documents consist of (a) worksheets or support documents used to fix the annual 'budget' for each producer on a country-by-country basis and (b) charts comparing the actual sales of each producer with their respective 'budgeted volumes', i.e. their quota for each regional and national market both on an annual basis and for the interim periods...."[32]

In other cases, cartels turned to third parties to collect, review, and sometimes aggregate data for use by individual cartel members. Members of the pre-insulated pipe cartel had their auditors certify "the total sales of pipes during the year, and the certificates were then exchanged among the cartel participants."[33] Some European cartels, such as the cartonboard cartel, took this one step further by engaging the services of Fides, a trust or fiduciary company, to assist in data collection:

> Fides is a fiduciary company located in Zurich which (amongst other activities) manages information exchange systems for various industries....In the context of the successful implementation of price initiatives, it was considered essential to develop a comprehensive system for the reporting and monitoring of production, sales volumes and capacity utilization. Most of the members of the PG Paperboard contributed periodic (weekly, monthly, six-monthly, annual) reports on orders, production, sales and capacity utilization to Fides....Under the Fides system the individual reports were collated centrally and the aggregated (and supposedly anonymized) data then sent to the participants.[34]

In some cases, the implementation of sophisticated monitoring and market allocation systems was accomplished by the development of a hierarchical structure within the cartel itself. Almost 40 percent of the cartels in our sample developed an internal hierarchy. For example, in the electrical carbon cartel, senior executives attended "summit meetings" held twice per year. These were followed by "technical meetings":

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[30] Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 2.
[31] Commission Decision of 16 December 2003, Case C.38.240 – Industrial Tubes, par. 85, 198.
[32] Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 191.
[33] Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 33.
[34] Commission Decision of 13 July 1994, Case IV/C/33.833 – Cartonboard, par. 27, 61-62.

> Technical Committee meetings [were] held twice a year to agree on price levels and percentage price increases for different products in different countries. … Local meetings [were held on an ad hoc basis to discuss price increases and accounts of single local customers.] Regular contacts … on a weekly and sometimes daily basis ... were necessary to ensure that the agreements were being upheld.[35]

Similarly, the copper plumbing tubes cartel designated a national "market leader" who "reported on developments in its home market to the other participants, so that these could better coordinate their behavior."[36] In a remarkable resonance to the U.S. electrical equipment conspiracy of the 1960s, in which different levels of management of the cartel received their own monikers, the copper plumbing cartel distinguished between the "elephant meetings" of top level managers and the "sweepers meetings" of operational managers.[37] Similarly, the citric acid cartel had its "masters" and "sherpas," and the graphite electrodes cartel had its "top level" group and "working level" group.[38]

The vitamin A cartel once again provides one of the most elaborate examples of this practice, with *four* layers of cartel management: top level, heads of marketing, global product marketing level, and regional product marketing level. The higher level managers met infrequently to set overall strategy, quotas and prices, and lower level managers met more frequently to monitor compliance at a global and regional level.[39]

As yet another mechanism for bolstering their monitoring effort, many cartels turn to trade associations to perform various monitoring activities. Twenty-nine percent of the cartels in our sample actively used trade associations to facilitate collusion. It would appear from Table 3 that the use of trade associations in our sample is similar to that found in earlier studies, but a closer examination suggests something different. Of the twenty-one cartels in our sample with trade association involvement, none involve a U.S. trade association. Fourteen cases involve pre-existing European trade associations whose activities in facilitating collusion probably pre-date

[35] Bertus Van Barlingen, "Commission fines five companies in carbon and graphite products cartel," *Competition Policy Newsletter*, No. 1, Spring 2004, p. 44.
[36] European Commission press release, "Commission fines companies in copper plumbing tubes cartel," Sept. 3, 2004.
[37] European Commission press release, "Commission fines companies in copper plumbing tubes cartel," Sept. 3, 2004.
[38] Kurt Eichenwald, "U.S. Wins a Round Against Cartel," *New York Times*, January 30, 1997, p. D1; Levenstein and Suslow (2004), p. 833.
[39] Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 172-188.

the recent changes in EU law and enforcement policies, which have made the legal environment much more hostile to price-fixing than in years past. Six of the seven trade associations that reach beyond Europe are related to shipping cartels that also evolved from associations or agreements that pre-date current competition policy. Several of these shipping associations were in fact formed after previous cooperative agreements were banned by the European Commission. Finally, one cartel (lysine) strategically formed an international trade association as a cover for its activities. Thus, it appears that American trade associations have learned to refrain from involvement in such conspiracies.

Despite a cartel's best efforts, individual firm sales do not always match assigned quotas. This may occur because of the cartel's inability to predict customer demand perfectly. Or it may occur because cartel participants cheat on the agreement. Cartels do their best to use the information gathering techniques described above to distinguish between cheating and random fluctuations in demand. Cartels do not want to disrupt collusion, losing profits and undermining trust, by retaliating when a firm has not cheated (or even sometimes when they know that a firm has cheated). On the other hand, they do not want to tolerate firms obtaining more than their allocated market share, as that simply rewards cheating and will undermine the cartel.

As a result, many cartels – 28 percent of our sample – adopt formal compensation rules. The simplest way to accomplish such compensation is with side payments. However, side payments leave a paper trail that increases the likelihood of successful antitrust prosecution. The most common compensation procedure for cartel members who have sold more than their share is to require them to purchase output from those who have sold less. Sales between competitors may have legitimate non-collusive justifications, but they are also very useful in facilitating collusion. These sales not only reduce a firm's incentive to cheat, they also eliminate the necessity for firms to agree on profits lost by the firm selling less than its allocated share. Again, Vitamin A provides a particularly well-developed example:

> [I]f one was seen to be selling more than its allocated quota, it would have to 'slow down' sales to enable the others to catch up. If at the end of the year a producer was substantially ahead of its quota, it had to purchase vitamins from the others in order to compensate them for the corresponding shortfall in their allocation.[40]

[40] Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 196.

We distinguish the use of a compensation scheme, agreed upon prior to the realization of market sales, from the use of punishments implemented when the cartel believes that a member reneged on an agreement. Where possible, we have identified the use of disciplinary actions imposed by the cartel in response to violations. While obviously the *possibility* of punishment—the threat of retaliation—is critical to cartel success, and was almost universal among the cartels studied here, the *implementation* of punishments is considerably less common than compensation schemes, occurring in only 13 percent of the cartels in our sample. In fact, where punishments do occur they seem to reflect not just violations of the agreement, but disagreements about what the terms of collusion should be. In some cases, the punishment took the form of a price war, as when a pre-insulated pipe producer (Løgstør) refused the terms proposed by ABB, the industry leader. This provoked "a strong negative and personal reaction from ABB" and a decrease in prices in major markets by 20%. It did not end the cartel: "the producers continued to meet, even if for some time the multilateral meetings were replaced by bilateral and trilateral contacts."[41] In other cases, price wars were not the punishment of choice. For example, Mitsubishi "tried to punish [other thermal fax paper producers] by cutting off their supply when they refused to sell the paper at the recommended prices."[42]

Combining this "punishments" category with exclusionary actions carried out by the cartel allows us to compare our sample characteristics to other studies. The exclusionary tactics are those mentioned earlier, such as restricting access to technology, targeted price wars, and acquisition of competitors. Thirty-nine percent of the cartels in our sample used some form of disciplinary or exclusionary tactics.[43] The frequency of these actions recorded in earlier studies, as shown in Table 3, is much lower: between five and twelve percent of cartels exhibited this behavior. Although it may be that cartels have grown more sophisticated in their use of punishments and exclusionary tactics, we expect that part of the reason for the difference lies in the more elaborate records currently made public by antitrust authorities.

In total, we have coded eleven cartel organization characteristics. Descriptive statistics are presented in Table 4 for the organizational variables (those ending with "ORG"), as well as the other variables included in the empirical model discussed below. In order to preserve degrees of

[41] Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 52.
[42] "Madhavi Acharya, "Toronto Company Files Mitsubishi Suit," *The Toronto Star*, Feb. 17 1999.

freedom, in some of our econometric specifications we combine these various organizational characteristics into one index called ORGINDX.[44] This eleven-point index assigns one point for each of the following cartel characteristics: bid rigging; market or customer allocation; agreement to standardize product characteristics or limit product quality; agreeing to other terms and conditions of sale; inclusion of distributors or producer/distributor firms; trade association participation; monitoring of output and pricing; disciplinary actions in response to cartel violations (cartel-imposed); compensation scheme or penalties for exceeding cartel quotas (self-imposed); exclusionary actions to prevent entry or expansion by non-members; and, organizational hierarchy within the cartel.

The mean value of the organizational index is 3.8, with a range from zero (the plastic dinnerware cartel, lasting less than a year) to eleven (the pre-insulated pipe cartel, involving ten vertically integrated firms and lasting about seven years). The KM comparison of the survival probability of cartels segmented by whether they had more or less than the average organizational level is shown in Figure 4. Cartels with greater organizational sophistication appear to be more likely to survive *at every age* than less organized cartels.

C. Measuring Cartel Duration and Tracing the Cause of Cartel Breakup

Given the variety of collusive punishments and the degree of discretion cartel participants have in choosing how and to what degree to punish, researchers face substantial challenges in determining when a cartel comes to an end, and when, or if, it begins anew. We rely heavily on descriptions of cartel activities provided by antitrust authorities. This has several implications for our measure of cartel duration. First, the start date for a cartel is often dictated by the information available to the enforcement authorities. It is clear that in many cases the authorities (or the customers) suspect that the cartel had earlier beginnings, but there is insufficient evidence to support prosecution based on earlier dates. Also, different firms can join a cartel at different dates, and sometimes cartels begin in one region and expand to other areas. In order to at least

[43] The 13 percent figure mentioned in the previous paragraph is a component of the 39 percent mentioned here. Other researchers using cross-section samples are not able to separately analyze the implementation of punishments.
[44] Griffin (1989) also creates a measure of internal cartel organization to capture the extent of control that the cartel has over member operations, but the information on which he bases his index is not clear. He states that it "is a subjective measure assigned after reading the available descriptions of the effectiveness of the cartel structure" (p. 191).

partially capture these nuances, we take the "birth" of the cartel to be the first known agreement between any two members of the cartel.

There are also difficulties measuring cartel breakup. In particular, the authorities do not distinguish between cartels that have continued to meet with little effect on price and those that are functioning effectively. In some cases, the cartels themselves are not sure whether the cartel has ended, as the following passage from the European Commission decision on the organic peroxides cartel illustrates:

> The parties confirm that around 1992, tensions between the companies were rising, but their views vary and differ as to the timing, intensity and duration of the tensions. In particular they disagree as to whether the agreement was terminated and later replaced or only certain contacts at high level were suspended. PC and Akzo consider the period of tensions to mark the end of one cartel and the beginning of another. Atochem, in contrast, sees the period of tensions not as the end of the agreement but as a period when the agreement did not work well.[45]

As we turn to the empirical analysis of cartel duration, it is important to keep in mind that we are measuring the *formal* breakup of an *informal* institution. In general we date the end of a cartel as when the cartel members give up trying to sustain collusion, as that is what is generally observable to us. As long as they are negotiating, it is clear that some members believe that there is a mutually beneficial collusive outcome. What is less clear is whether they have located a set of equilibrium strategies that will support such an outcome.

To analyze the determinants of cartel breakup, we have coded the "cause of death" for each of the cartels in the sample (Table 5). The broadest distinction is between those cartels for which the proximate cause of breakup was government antitrust enforcement, and those that dissolved for other reasons, such as cheating or a growing fringe of non-cartel producers. In order to identify precipitating factors of antitrust investigations, it is important to understand the recent evolution of antitrust enforcement in the United States and the European Union. The U.S. Department of Justice (DOJ) has had a corporate amnesty program since 1978, but it was largely ineffective because of the ambiguity surrounding whether a company would qualify for amnesty. In 1993, the DOJ revised and expanded its amnesty policy, offering *automatic* amnesty from fines and jail terms to the first cartel member who voluntarily and prior to any governmental

[45] Commission Decision of 10 December 2003, Case COMP/E-2/37.857 – Organic peroxides, par. 131.

investigation offers evidence of a cartel and agrees to cooperate in its investigation.[46] The number of corporations coming forward and seeking amnesty rose in the early 1990s from roughly one per year to one per month.[47] This trend has continued to accelerate: by 2003, the DOJ was receiving roughly two amnesty applications per month.[48] The percentage of foreign defendants has also risen dramatically.[49]

The European Commission (EC) also has an amnesty policy, first implemented in 1996 and then revised and strengthened in 2002. The EC grants full immunity to the first company to submit sufficient evidence which allows the Commission "to launch an inspection at the premises of the companies allegedly involved in the cartel."[50] Some companies will simultaneously apply to multiple jurisdictions for amnesty, as Christie's art auction house did in 2000.[51] As shown in Table 5, there are eleven cartels in our sample that ended due to an application for amnesty, and these cartels lasted an average of 9.5 years.

We distinguish these amnesty-instigated investigations from cartel breakups where a government-initiated investigation *followed* from the investigation of another cartel. There are thirteen such cartels in our sample, with an average duration of 8.2 years. There are formal and informal ways that follow-on prosecutions can occur. The DOJ has an "Amnesty Plus" program that offers leniency to firms caught in the investigation of a cartel for which they are not eligible for amnesty if they provide information about a second cartel that was previously unknown to

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[46] See Department of Justice Antitrust Division, *Leniency Policy Documents*, *available at* http://www.usdoj.gov/atr/public/criminal.htm (linking to the current corporate and individual amnesty policies of the U.S. Department of Justice).

[47] *See* Anne K. Bingaman, *Opening Markets and Protecting Competition for America's Businesses and Consumers: Goals and Achievements of the Antitrust Division, U.S. Department of Justice, Fiscal Year 1993 through March 1996*, Report for 1996 Spring Meeting of the Section of Antitrust Law 8 (1996).

[48] R. Hewitt Pate, "The DOJ International Antitrust Program – Maintaining Momentum," Address Before the American Bar Association Section of Antitrust Law (Feb. 6, 2003), *available at* http://www.usdoj.gov/atr/public/speeches/200736.htm. Pate states that: "The Division's leniency program has played a major role in cracking the majority of the international cartels that the Division has prosecuted. The application rate has surged over the last year to better than two per month" (p.6).

[49] Adler and Laing (1997): "In 1991, only 1 percent of corporate defendants were foreign and no foreign individuals were charged that year. From July 1996 to January 1997, 20 percent of all corporations and 27 percent of all individuals charged were foreigners" (p. 1).

[50] European Commission Leniency Policy, available at http://ec.europa.eu/comm/competition/antitrust/leniency. There are other conditions required for full immunity, such as putting an immediate end to the infringement and not playing a role as the ring leader of the cartel. See, European Commission, Directorate-General for Competition, 32nd Report on Competition Policy, 2002, p. 18 (*available at* ec.europa.eu/comm/competition/annual_reports/2002/report_short_en.pdf).

the authorities.[52] The European Commission does not have a formal "amnesty plus" process, but there are often cases where it is clear that the EC discovered a cartel as the result of an earlier cartel investigation. In the private label beer cartel in Belgium, for example, Interbrew informed the European Commission while it was being investigated regarding a separate beer cartel (also in Belgium).[53] Takeda, a Japanese chemical firm, informed the European Commission about the cartel in nucleotides (a food flavor enhancer) in September 1999, when the vitamins cartels, of which it was also a member, began to unravel due to government investigations which began the year before.[54]

Since the DOJ rarely publicizes who receives Amnesty Plus, we have in most cases inferred whether a cartel investigation was a direct follow-on from an earlier investigation, both for DOJ and EC cases. Amnesty plus applications, or less formal efforts to "come clean" about all industry cartels once a cartel is discovered in one product line, are generally offered under the duress of antitrust prosecution. We therefore expect that the determinants of when a cartel is broken up by follow-on confessions once one cartel is uncovered will differ from those offered under a voluntary amnesty plan.

Some government prosecutions are instigated not by producers, but by customers. In our sample there are eight cases where a customer complaint triggered an investigation and the eventual breakup of the cartel. These cartels had an average duration of 5.3 years. The first vitamin cartel to be investigated (vitamin E) falls into this category, as do the cross-channel ferry operators cartel, graphite electrodes, thermal fax paper, stainless steel, and several shipping cartels.

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[51] "Christie's approached regulators on both sides of the Atlantic in 2000 and owned up to wrongdoing in exchange for leniency which could take the form of a reduced fine." (Osborne, Andrew, "Sotheby's, Christie's in price scam, says EC," *The Guardian*, 20 April 2002.)

[52] The amnesty plus program is summarized in Hammond (2004). There is also a policy known as "affirmative amnesty" the DOJ will offer amnesty to firms in return for their cooperation in an investigation, even when the DOJ already has knowledge of a cartel's existence, in order to obtain the evidence necessary for a prosecution. See Hammond (2006), p. 11.

[53] European Commission press release, "The Commission fines brewers in market sharing and price fixing cartels on the Belgian market," Dec. 5, 2001.

[54] Commission Decision of 17 December 2002, Case COMP/C.37.671 — Food flavor enhancers, par. 43. The EC decision on the vitamins cartel documents the fact that the vitamins case broke in 1998: "On 8 May 1998 the District Court of Northern Texas issued a Grand Jury subpoena on Roche's US subsidiary company in connection with investigations by the Justice Department into the vitamins market." (Commission Decision of 21 November 2001, Case COMP/E-1/37.512 — Vitamins, par. 149.)

Finally, the last category of government breakup of cartels comes from those cases where an agency investigation arises from any remaining sources of information (other than amnesty applications, follow-on investigations, and customer complaints). This is in fact the most numerous category for our sample: 28 of 72 cartels fall into this category, with average duration of 7.6 years. In the chemical tankers, ferrosilicon, citric acid and lysine cases, for example, a whistleblower triggered the investigation.[55] In the memory chip cartel, a Dell executive publicly blamed memory chip price increases on cartel-like behavior, prompting more general awareness among customers about the price increases as well as government investigations.[56] In the pre-insulated pipe cartel, it was a competitor who sent a complaint to the EC. This cartel made numerous attempts push Powerpipe out of business, or at least keep it from expanding from Sweden into Germany, the most lucrative market for the cartel. Powerpipe alleged to the Commission that cartel members "had taken concerted steps to damage the business of Powerpipe and/or confine its activities to the Swedish market and/or drive it out of business altogether by (inter alia) systematically luring away key management personnel and unlawfully interfering with its contractual relations with customers and suppliers."[57]

There are often multiple factors that contribute to cartel breakup. For each cartel in our sample, we have attempted to select the factor that was most significant in the cartel's final breakup. There are only two cartels in our sample that we code as breaking up primarily due to cheating, and they lasted a brief 1.5 years on average. The short-lived aluminum phosphide cartel, for instance, ended because one firm charged substantially lower prices than the target price set by the cartel.[58] There are, however, numerous cartels where cheating was an issue either intermittently or throughout the life of the cartel. Some of these cartels eventually ended when a firm applied for amnesty, and we code them as ending due to government investigation triggered by an amnesty application. Thus, for many of the cartels cheating was a fact of life—a reality of running the organization—but not a cause of death.

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[55] We distinguish whistleblower-initiated investigations from amnesty applications because these are cases where the DOJ or EC was informed by the whistleblower *on their own behalf*. In contrast, when companies apply for amnesty, it is on behalf of the entire company and all of its executives.
[56] Kanellos, Michael, "Dell Trying to Sidestep Chip 'Cartel'," CNET News.com, April 30, 2002.
[57] Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Preinsulated Pipe Cartel, par. 20.
[58] Dauner, John T. "Foreign conspiracy Trial Begins in KCK Others Already Have Pleaded Guilty to Similar Charges," *The Kansas City Star*, July 14, 1994.

Cartels that broke up on their own due to a growing fringe (prior to any antitrust action) lasted on average 6.4 years. Several of the vitamins cartels fit into this category. The vitamins cartels for B1, B2, and B6, for example, all ended primarily due to growing Chinese exports. Cheating was also an issue, particularly in the B2 cartel, but entry of Chinese production was the catalyst. For vitamin B6 it was particularly pronounced, with the Chinese share growing from three percent of the world market in 1991 to forty-eight percent in 1993: "Roche says that by the first half of 1994 the parties recognised that the vitamin B6 agreement was no longer viable owing to the Chinese imports and decided to end the agreement."[59]

Cartels that applied for amnesty, prior to any known antitrust investigation of their firm, were actually relatively long-lasting cartels (with an average duration of 9.5 years), contrary to what the theoretical discussion above suggested. Even those that were terminated as a result of a follow-on investigation, having been discovered colluding in other markets, were relatively long-lived (with an average duration of 8.2 years). This suggests that amnesty and leniency policies have been able to disrupt long-lived cartels. Figure 5 confirms this, by contrasting the KM survival function for cartels broken up by amnesty applications, other causes of antitrust investigations, and cheating or competition from a growing fringe. What is perhaps most interesting about this picture is that the cartels ended by applications for amnesty do not appear to have been shorter lived. At least over the last fifteen years, it appears that the U.S. Justice Department's amnesty program and the European Union's more recent leniency program have caught quite long-lived cartels in their net.[60]

IV. EMPIRICAL MODEL

A. Hazard Model

In order to examine these issues empirically, we estimate a proportional hazard model, specifying the probability of cartel breakdown as a function of variables thought to influence the

[59] Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 348.

[60] Harrington (2006) presents a theoretical model designed to characterize the change in the distribution of cartels (by cartel age) resulting from a change in antitrust policy, and the distribution of those cartels caught by the government. He summarizes one of his main theorems relating antitrust enforcement and cartel duration as follows: "…a rise in [detection and conviction] causes the immediate collapse of the least stable cartels…. This means the surviving cartels are those [of] … longer duration. Since this is the pool from which one draws discovered cartels, the average duration of discovered cartels rises in the short-run in response to a more aggressive detection and conviction policy" (p. 15). Our descriptive empirical statistics support Harrington's theoretical conclusions.

stability of collusion. The hazard function h(x) is the ratio of the probability density function f(x) to the survival function S(x), given by

$$\lambda(x) = \frac{f(x)}{S(x)} = \frac{f(x)}{1 - F(x)},$$

where $F(x)$ is the cumulative distribution function. The hazard rate is the probability that an event occurs (i.e., the cartel dissolves) at time t, given that it has not already occurred.

A proportional hazard model with a vector of covariates, $\mathbf{x}$, can be written as

$$\lambda(t; \mathbf{x}) = \kappa(\mathbf{x})\lambda_0(t),$$

where $\kappa(.)>0$ is a nonnegative function of x and $\lambda_0(t)>0$ is the underlying or baseline hazard. The baseline hazard is common to all subjects in the population. It is invariant across cartels, but can be any separable function of time. Individual hazard functions differ proportionately based on a function $\kappa(\mathbf{x})$ of observed covariates. Typically, $\kappa(.)$ is parameterized as $\kappa(\mathbf{x})=\exp(\mathbf{x}\boldsymbol{\beta})$, where $\boldsymbol{\beta}$ is a vector of parameters and $\exp(\mathrm{x}\boldsymbol{\beta})$ is a shift factor that depends on cartel or industry characteristics. Taking logs of both sides yields:

$$\log \lambda(t; \mathbf{x}) = \mathbf{x}\boldsymbol{\beta} + \log \lambda_0(t),$$

where β_j measures the semi-elasticity of the hazard with respect to x_j.

In our application we are interested in how the covariates shift the hazard function, in which case the estimation of λ_0 is not necessary. Cox (1972) obtained a partial maximum likelihood estimator for $\boldsymbol{\beta}$ that does not require estimating λ_0.

Let us assume now that

$$\lambda(t; \mathbf{x}) = \lambda_0(t) e^{(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p)},$$

where $\lambda(t;\mathbf{x})$ is the hazard at time t for a cartel with covariate vector $\mathbf{x} = (x_1, x_2, \ldots, x_p)$. The parameter vector $\boldsymbol{\beta}$ is estimated via a maximum likelihood approach.

Note that if we change the measurement of one covariate, say x_1, by one, and keep other covariates unchanged, then the *relative risk of breakup* is

$$\frac{\lambda_0(t)e^{(\beta_1 x_1+\beta_2 x_2+\ldots+\beta_p x_p)}}{\lambda_0(t)e^{(\beta_1(x_1-1))+\beta_2 x_2+\ldots+\beta_p x_p)}} = e^{\beta_1(x_1-x_1+1)} = e^{\beta_1}.$$

Thus, the estimated coefficient is the natural logarithm of the hazard rate ratio when x_1 is increased by one unit. We estimate the probability that a cartel that has lived to year $t - 1$ breaks up in year t as a function of the parameter vector β which includes characteristics of the cartel, the market, and the economic environment in year t. An estimated hazard rate ratio greater than one indicates that the covariate is associated with an increased hazard of cartel breakup. A hazard ratio less than one indicates that an increase in the covariate is associated with a decrease in the hazard or failure rate.

B. Determinants of Cartel Duration

We estimate the determinants of cartel duration, including variables whose fluctuations are likely to cause violations in the participation constraint and variables that reflect the cartel's ability to prevent, absorb, or respond to shocks.

In order to measure the impact of fluctuations in firm impatience on the probability of cartel breakup, we include several alternative specifications of the discount rate of cartel member firms. Assuming that there are efficient capital markets to which all firms have equal access, the market interest rate is the best proxy of the (common) discount rate of all cartel members. We use the average annual interest rate on three-month Treasury Bills, which represents the short-term market rate of interest available to borrowers in international markets.

Because it is possible that some firms face differential access to credit markets, we have also created two firm-specific measures that capture financial distress for individual firms, following the approach taken by Busse (2002).[61] These variables are standard measures of firm indebtedness, namely the leverage ratio and interest coverage, and are defined as follows:

Leverage ratio:

(Total equity – Net stockholders' equity) / Total equity

[61] An alternate, and frequently used, method of assessing whether a firm is financially sound is to construct Altman's "Z-score" (Altman, 1968). The Z-score is calculated as a weighted average of five financial ratios. Although these ratios are generally calculable from Compustat data, because of the international nature and time span of our sample the data were not consistently available.

Interest coverage:

(Operating profit – Non-operating expense + Depreciation) / Interest expense.

We construct these ratios at the firm level for each cartel member firm in our cartel dataset using data from Compustat.[62] In order to focus on changes in the discount rate that might disrupt cartel stability by causing a violation of the participation constraint, we define the annual *cartel* interest coverage each year as the minimum interest coverage ratio across all member firms. Analogously, we define the annual cartel leverage ratio as the maximum leverage ratio across all member firms in that year. For example, for a given year for cartel j, we use

$\max\{\text{leverage ratio}_i \mid \text{for all firms } i \text{ in cartel } j\}$ as cartel j's leverage ratio; and

$\min\{\text{interest coverage}_i \mid \text{for all firms } i \text{ in cartel } j\}$ as cartel j's interest coverage ratio.

These two variables, INTCOVERAGE and LEVRATIO, are intended to capture the effect on cartel duration of the most financially unstable firm in the cartel, and hence the firm with the greatest incentive to cheat. By construction, these variables are allowed to vary over time within a cartel, representing the most financially vulnerable cartel member. Although LEVRATIO is fairly stable, INTCOVERAGE varies quite a bit over a given cartel's lifespan.

There has been considerable discussion, though much less consensus, regarding the effect of macroeconomic fluctuations on cartel stability. Green and Porter (1984) propose a model in which negative shocks to demand lead to the appearance of cartel breakup. Rotemberg and Saloner (1986) propose an alternative model in which cartels become less effective during macroeconomic booms. Haltiwanger and Harrington (1991) reverse the Rotemberg and Saloner result by introducing auto-correlated shocks to demand. Previous cross-sectional studies have found that macroeconomic volatility reduces cartel life spans (Suslow 2005, Dick 1996). We examine this issue with respect to our sample of contemporary international cartels by estimating the effect of deviations from trend global GDP.

[62] We use Compustat North America (Industrial Annual) for U.S. firms and Compustat Global (Industrial/Commercial) for non-U.S. firms. Details on the construction of these measures are provided in the Appendix.

We measure demand fluctuations that might disrupt collusion by estimating a non-linear trend in GDP using the Hodrick-Prescott filter (1997).[63] The HP filter fits a smooth nonlinear trend curve to a time series by decomposing it into a non-stationary trend component and a stationary cyclical component. Since relatively sophisticated firms are unlikely to be confused by predictable macroeconomic fluctuations, we hypothesize that it is deviations from this trend that may disrupt collusion. In some theoretical specifications, cartels are disrupted by *negative* shocks to demand. In others models it is demand variability more generally, including rapid demand growth, which is disruptive to collusive stability. We calculate the difference between actual GDP and the HP filter, and distinguish between positive and negative shocks.

Dick (1996) models demand shocks with a first-order autoregressive process, AR(1).[64] Although we could use a similar AR(1) linear regression in order to estimate the trend in GDP, we believe that using the HP filter allows for more sophisticated understanding of macroeconomic phenomenon on the part of cartel participants. Managers remember more than one period, and they can imagine economic shocks that are not linear. The HP filter, a smoothed non-linear (weighted moving average) of the original series, accommodates this. In other words, focusing on deviations from this non-linear trend assumes that managers have a sense of what is going on in their market that is not limited to a simple linear extrapolation of current events.

Because these are international cartels, fluctuations in exchange rates are also potentially disruptive to collusion. [65] Cartel agreements reflect both the market price and production costs. Fluctuations in exchange rates can affect both of these, and affect cartel members producing in different countries asymmetrically so that previously agreed cartel prices and market shares may no longer be sustainable. In order to capture this effect, we include the absolute value of the change in the exchange rate of the U.S. dollar (using a trade-weighted index).

We also consider the impact that the number of cartel members has on cartel stability. The participation constraint suggests that, within in a single industry, cooperation can be sustained as

[63]The HP filter is a weighted moving average, where the researcher must specify the weight, or smoothing parameter, commonly denoted by λ. The choice for λ recommended by Hodrick and Prescott varies with the frequency of the data. We have annual GDP data, and thus we set $\lambda = 6.25$ (Ravn and Uhlig, 2002).

[64] See Dick (1996), pp. 270-271. Dick defines business cycles using export price indexes and then decomposes export price movements into anticipated and unanticipated components. He finds that Webb-Pomerene export cartels between 1918 and 1965 were more prone to failure during anticipated downturns, but that the effect of unanticipated business cycle changes was insignificant.

[65] See Alexander (2003) for an elaboration and illustration of the impact of exchange rates on cartel stability.

long as the number of firms is below some critical threshold. Because the number of firms may not affect cartel stability in a linear fashion, we have created a dummy variable MEM_OVER5 that indicates whether the cartel has a "large" number of firms. This "more than five" threshold is consistent with theoretical results that show that cooperation is much more difficult with large numbers of participants.[66]

As discussed in the theoretical section above, *customer* concentration may also be an important determinant of cartel stability. Stigler (1964) hypothesized that collusion would be more effective against buyers engaging in small purchases. In his study of legal Webb-Pomerene export cartels, Dick (1996) tests Stigler's hypothesis by constructing a measure of customer concentration, proxied as the market share of the four largest consuming countries of each Webb-Pomerene association's exports. He finds that Webb-Pomerene cartels selling into relatively more concentrated consuming markets tended to be less stable.[67] There is anecdotal evidence, however, suggesting that cartels treat large customers differently, reducing their destabilizing effect.[68] In the electrical and mechanical carbon products cartel, for example, large customers had bargaining power and did not always accept the announced cartel price. In the sorbates cartel, producers explicitly set a separate target price for the largest or "ultrabig" purchasers.[69]

While we have no data on customer size for the firms in our sample, we have followed Dick in constructing a measure of downstream industry concentration. We define the variable CUSTCONC as the HHI of the primary downstream consuming industry (defined at the 4-digit SIC or 6-digit NAICS level) for each cartel. We obtain HHI estimates from the quinquennial U.S. Census of Manufacturing, 1982 to 2002.[70] This measure varies from our ideal measure in two ways. First, we must choose one primary downstream industry. Since the primary

[66] Selten's (1973) classic article presents a Cournot model of cartel formation where the dividing line between "small" and "large" is five firms. As he explains in the introduction, the basic intuition for this result is the "fact that the position of an outsider becomes relatively more attractive as the number of competitors is increased…" (p. 142). We test for other threshold values for our "MEM_OVER" dummy variable, such as 4 and 6, but the MEM_OVER5 variable performed the best. See the results section below.
[67] Dick (1996), p. 261.
[68] See Levenstein and Suslow (2006), pp. 61-64, for a review of the empirical literature on the relationship between customer size and cartel stability.
[69] Commission Decision of 3 December 2003, Case C.38.359- Electrical and Mechanical Carbon and Graphite Products, par. 76 and 106, as examples. For the sorbates cartel, see "United States of America v. Yuji Komatsu, Yoshihiko Katsuyama, Wakao Shinoda, and Hitoshi Hayashi" Indictment, Jan. 23, 2001, *available at*: http://www.usdoj.gov/atr/cases/f7300/7366.htm.

consuming industry represents only a portion of cartel sales, our measure over-estimates downstream concentration. However, if the portion of sales to the primary consuming industry is roughly uniform across cartels, then the variation in our measure of concentration will correctly capture the variation in customer concentration faced by the different cartels in our sample. To the extent that the diversification of sales across consuming industries varies across cartels, we have unmeasured variation that our variable CUSTCONC misses. Second, our measure of concentration is based on the concentration of U.S. consuming industries. While the U.S. Census Bureau data gives us a consistent measure that spans our sample period, it is possible that customer industry concentration varies across the national markets in which these international cartels operated, again giving rise to unmeasured variation. Despite the problems with this measure, it does allow us to begin to address an issue that has been frequently discussed but infrequently studied empirically in previous studies.

Finally, ideally we would like to control for differences in the elasticity of demand across industries. Unfortunately, we simply do not have the necessary to data to estimate demand elasticities across all of the industries in our cross-section. Therefore, in order to control for at least some idiosyncratic differences across industries, we include sector dummy variables for the broad industry group in which each cartel operates. These are, as listed in Table 4 along with their means, CHEM (chemicals sector), MTL&MINRL (metals and minerals), OTHMFG (other manufacturing, such as carbonless paper and haberdashery products), and NONMFG (non-manufacturing industries, such as services, water transportation, and construction).[71]

V. Regression Analysis

A. Full-Sample Results

We first estimate the determinants of the probability of cartel breakup on the full sample (Table 6), and then look at several sub-sample estimates, focusing on particular variables of interest where data availability was limited. Parameter estimates greater than one indicate that

[70] Further details on how this variable was constructed are given in the Appendix.

[71] In his theoretical model, Harrington (2006) also chooses to broadly parameterize industries, and explains his motivation as follows: "In modelling a population of industries, it is compelling to allow industries to vary in terms of cartel stability. For this purpose, I assume industries may differ in terms of the parameter η. If one takes this assumption literally, it can be motivated by heterogeneity in the elasticity of firm demand or the number of firms (as

the variable has a positive effect on the probability of cartel breakup. Parameter estimates less than one indicate that the variable decreases the probability of breakup, increasing cartel stability and expected duration.

We find that increases in organizational sophistication are generally associated with increases in cartel duration. Our econometric specifications with disaggregate organizational characteristics focus on those organizational features for which we have the best and most reliable measures: market allocation mechanisms, monitoring, the development of a complex hierarchy within the cartel, and whether the cartel used compensation or other sorts of punishments when participants violated the cartel agreement. Cartels that used market allocation mechanisms were significantly less likely to break up than those that did not (Table 6, models 1 and 2). Our point estimate of 0.31 implies that the use of market allocation mechanisms reduced the probability of breakup by 69 percent. The other elements of our organizational measure are not statistically significant. In order to preserve degrees of freedom and to better capture overall organizational sophistication we combine all eleven cartel characteristics into ORGINDX (Table 6, model 3). Increases in this organizational index significantly reduce the probability of cartel breakup: an increase of one in ORGINDX decreases the likelihood of cartel breakup by 12 percent.

The coefficient on Mem_OVER5 (a dummy variable indicating whether a cartel had more than five members) is greater than one, as hypothesized. This suggests that large cartels are more likely to dissolve, all else equal. In results not reported here, we instead included the number of cartel participants in the specification and found similar results. However, in neither case is the coefficient significantly different from one. Variables measuring the number of cartel members, however constructed, may have a larger effect on the industries in which collusion is attempted than on how long the cartel lasts. We discuss our cartel member variable further below in estimates where we also control for industry concentration.

Perhaps the single most robust result of the repeated game literature on collusion is that as players become more impatient, collusion is harder to sustain (Friedman, 1971). This prediction has rarely been tested in cross-section studies; we do so here by including a measure of short

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with the Bertrand price game). Our intent is not to be literal but rather to think of this as a parsimonious way in which to encompass industry heterogeneity" (p. 5).

term interest rates (TBILL, the 3 month Treasury-bill rate). Somewhat paradoxically, we find that increases in the rate of interest significantly *decrease* the probability of cartel breakup (Table 6, models 1, 2, and 3). There are several possible explanations of this result. First, it may be that using T-bill rates confounds the discount rate and overall macroeconomic fluctuations. Interest rates tend to increase during macroeconomic expansions, and cartels are generally believed to be more likely to dissolve during macroeconomic contractions. Second, it may be that this particular measure of the interest rate does not reflect the discount rate of cartel participants. In particular, short-term fluctuations in market interest rates may be less important than the overall time horizon of cartel participants. Firms that are likely to respond to short-term fluctuations in market interest rates may not have the long horizon necessary to sustain, or even attempt, collusion. In order to address these concerns, we develop and test alternative measures of the discount rate. Because of data availability problems, the use of these firm-specific measures reduces our sample size. We discuss these results further below.

Turning to our full-sample estimates of the direct impact of macroeconomic fluctuations, we examine the effects of shocks to GDP. We include positive and negative shocks to GDP as separate variables in order to allow the data to tell us whether cartels responded to economic upturns and downturns symmetrically. As described above, we measure shocks as the difference between actual and trend GDP, with the GDP trend determined by the Hodrick-Prescott filter. If actual GDP is greater than trend, the variable POS_HP takes the value of the difference and the variable NEG_HP takes the value zero. Analogously, if the difference between actual GDP and trend GDP is negative, POS_HP takes the value zero and NEG_HP takes the value of the difference. We find that positive shocks to GDP have no impact on cartel stability (Table 6, model 1). However, *negative* deviations from trend GDP show a consistent, statistically significant impact on the probability of breakup. A negative shock to GDP of the average size of such shocks over this period would increase the probability that a cartel would fail by 48 percent (Table 6, model 1).[72]

[72] The calculation of 48 percent is based on multiplying the un-rounded coefficient on HP_NEG, 1.006786, by the mean of HP_NEG, -70.96 (Table 5). We also tried a specification of demand "shocks" including squared deviations from the HP trend to capture the idea that large deviations, in either a positive or negative direction, may disrupt collusion. This measure had no significant effect on the probability of cartel breakup.

Others have suggested that rapid growth in demand as well as overall volatility may disrupt cartels.[73] Marquez (1994) uses a weighted average of GNP growth rates for Germany, Japan, the UK, and U.S., where the weights are the proportion of cartel members from that country. He finds that faster demand growth reduces cartel duration, but the coefficient is insignificant (p. 338). The comparable measure for our sample would be global GDP growth. While the results are not reported here, the coefficient on GDP growth was not significant in any of the specifications estimated. It may be that an analysis of individual cartels would find a causal relationship between demand growth and cartel breakdown, but that this relationship is not captured by global GDP growth, which may mask industry or product specific trends. It may also be that previous international cartel cross-section studies that found a significant relationship between macroeconomic volatility and cartel duration (Marquez 1994, Suslow 2005) were picking up the effect of a unique historical episode, as these studies examined cartels that spanned the Great Depression of the 1930s.

We find that exchange rate fluctuations had no significant effect on cartel stability (Table 6, models 1, 2, and 3). Again, this may reflect the difficulty in capturing the shocks to individual cartels using aggregate data (in this case, a trade-weighted index of the value of the U.S. dollar). The relevant fluctuations in the exchange rate depend on the location of production for cartel participants and the regions in which the cartel participants agree to fix price. The nationality of cartel members as well as the geographic scope of the cartels varies over the sample. Therefore, different pairwise exchange rates may better capture the shocks faced by individual cartels, but adding pairwise exchange rates for each of the countries with cartel participants (and customer markets) in this sample of global cartels would exhaust the degrees of freedom provided by the size of our sample.

Our controls for the sectors in which the cartel participates (Table 6, model 3) suggest that cartels in the chemical industry may be longer lived than cartels in other industries. This may reflect differences in elasticity of demand, as we suggested above. Alternatively, it may reflect the long history of collusion among the firms in this particular sector.[74]

[73] Marquez (1994), p. 332.
[74] For histories of cartels in the chemical industries, see Haber (1958, 1971), Stocking (1931), and Stocking and Watkins (1946, 1948).

B. Measures of Concentration and Financial Distress

We now turn to our examination of several determinants of cartel stability for which there were particularly difficult data problems. As a result, the inclusion of each of these variables reduces the sample size. The reader is cautioned that the sample varies across the specifications we report here, and that with such a small sample the change in sample composition may have confounding effects. In results not presented here, we test for pure sample effects by comparing the parameter estimates obtained for the full-sample models 1, 2, and 3 when estimated only on these sub-samples. In no case does the reduction of sample size change our qualitative results: there is no reversal in the direction of the effect of the variables. However, statistical significance is reduced by the reduction in sample size. In order to preserve degrees of freedom, we conduct these analyses using ORGINDX, our aggregate index of the various cartel organizational features.

1. Producer Concentration

Our measure of industry concentration is MINC4, the minimum four-firm concentration ratio during the life of the cartel (see Table 4 for descriptive statistics). In some cases we have the actual C4, while in others we estimate MINC4 using market share data on the top two or top three firms, if that is all we were able to obtain. For example, the bromine cartel lasted from 1995 to 1998 and at that time the world market consisted of three major producers.[75] The three-firm global concentration ratio was 83 percent in 1998.[76] The C4 would certainly be higher, but at a minimum it would be at least 83 percent.

As has been the case in previous cross-sectional studies, industry concentration does not have a significant effect on cartel duration (Table 7, model 4). However, the inclusion of the concentration ratio variable increases the size and statistical significance of the variable MEM_OVER5, reinforcing our prior belief that increasing the number of firms in a cartel has an economically and statistically significant effect on the likelihood of cartel breakup. It may be that without controlling for industry concentration, that effect was masked.

[75] Joseph Chang, "Market for Brominated Flame Retardants Remains under Pressure," *Chemical Market Reporter*, Sept. 27, 1999 (p. 3).
[76] Susan Warren, "Great Lakes is Assisting Bromine Probe," *Wall Street Journal*, June 16, 1999 (p. A3).

2. Customer Concentration

Adding our measure of customer concentration (the United States HHI of the primary consuming industry), reduces the sample size from 72 to 44 cartels. The coefficient on CUSTCONC is 1.00, showing no effect of differences in customer concentration on cartel stability. While this may reflect our small sample size or our inability to measure global concentration of the consuming industry, this result is consistent with our general observation that large customers do not increase the incentive of firms to cheat on the cartel. Rather, these large customers simply receive discounts—agreed upon by cartel members—from the cartel price. The general results are otherwise quite similar to our earlier specifications. Increased organizational sophistication and higher interest rates are associated with less likelihood of cartel breakup. Negative shocks to GDP have a small but statistically significant positive effect on the likelihood of cartel breakup.

3. Financial Distress

Given the perverse results that we find for the effect of fluctuations in market interest rates on cartel stability, it seemed desirable to identify an alternative measure of firm impatience. Due to data limitations created by the international nature of our sample and the time period, the number of cartels in the sample falls to 56. We report statistically insignificant but nonetheless quite thought-provoking results. When the variable INTCOVERAGE was included (in results not reported here), it had the expected sign. In Table 7, model 6, we report the results using a slightly different variable, INTCOVERAGE<1: this dummy variable indicates whether any member of the cartel had insufficient net income in a particular year to cover its annual required debt payments. The coefficient on the interest coverage variable is 1.52, indicating that the presence of a cartel member with income insufficient to cover interest payments increases the probability of cartel breakup by 52 percent. Although this variable performs better than the continuous variable (INTCOVERAGE), the coefficient is statistically insignificant. Our second measure of firm-specific impatience is the firm leverage ratio. Again, we focus on the most leveraged firm in the cartel, and find that increases in the leverage of the most leveraged firm in the cartel increases the likelihood of cartel breakup (by 256 percent), but the result is not statistically significant.

C. Competing Hazard Model and Cause of Breakup

In order to capture the effects of antitrust policy on cartel breakup, we estimate a competing hazard model in which we examine the determinants of "death by antitrust investigation" as distinguished from other causes of cartel breakup.[77] We are particularly interested in two issues: first, if there are antitrust breakups that are not related to economic fluctuations, we may get more precise estimates of the effects of economic fluctuations if we distinguish the cause of breakup. Second, we would like to better understand whether government amnesty and leniency programs affect cartel stability, and if so, how. Do these programs disrupt cartels that are on the verge of falling apart, as suggested by the theoretical analysis above, or are they targeting the most successful cartels, as suggested by the longevity measures reported above?

Because firms elect when to apply for amnesty, we assume that variables that affect cartel stability and profitability will affect the decision to apply for amnesty. We would not expect those variables to affect other types of antitrust investigations of cartels, including the antitrust follow-on cases. Unfortunately, splitting the sample into different causes of failure greatly reduces sample size. The resulting estimates are imprecise and generally not statistically significant. We present them here because the questions are important for both theory and antitrust policy, and we believe they provide a starting point for an empirically-informed discussion of these issues.

We find that increases in the extent of cartel organization significantly decrease the likelihood of breakup (by 14 percent) for those cartels eventually broken up by the antitrust authorities. Our point estimate of the effect of cartel organization on the stability of those cartels that break up on their own is similar, but is not statistically significant. Our point estimates also suggest that antitrust investigation and breakup are more likely for cartels with more than five members, while breaking up on their own is more likely for smaller cartels, but this finding is statistically insignificant (Table 8).

[77] For general discussion of competing risks models, see Katz and Meyer (1990) and Hill et al. (1993).

VI. CONCLUSION

In order to interpret the results presented here correctly, we must be clear about what we are measuring when we measure cartel duration. Cartel duration is not the same as cartel success. In fact, the cartels most successful at raising price may not endure if they also encourage entry.

Industry concentration may influence where cartels are attempted, but differences in concentration do not appear to affect duration. In general, shocks to the economic environment can destabilize a cartel's equilibrium price and output allocation, and eventually cause the end of the cartel. In particular, as suggested in some theoretical models, negative deviations from trend growth have a negative impact on cartel stability.

Despite the destabilizing effect of negative economic shocks, we find that there are durable cartels that develop mechanisms to cope with such economic variability. Cartels have developed sophisticated organizational mechanisms that limit the incentive to cheat, monitor each other's actions, and create barriers to entry. We consistently find that cartel organization facilitates cartel longevity. Assigning markets or customers to firms is a particularly effective tool for extending cartel life.[78] Thus, international markets may be much more amenable to collusion than has generally been presumed by advocates of unregulated globalization.

Amnesty and leniency policies have become an important tool in antitrust authorities' battle with international cartels. The empirical results presented here, though preliminary in nature, suggest that the cartels induced to apply for amnesty are longer lasting than the average cartel. While there are theoretical reasons to expect that firms will report the least profitable cartels, the evidence here does not suggest any systematic differences between those cartels offered up for amnesty and other cartels.

[78] Stigler (1964) made this point: "Fixing market shares is probably the most efficient of all methods of combating secret price reductions" (p. 46).

APPENDIX

Cartel Data: Information on the number of cartel members, the dates of operation of the cartel, the various organizational characteristics of the cartel, market shares and four-firm concentration ratios come from a variety of publicly available sources. These sources are primarily Department of Justice, European Commission, and Canadian Competition Bureau press releases, European Commission decisions, and judgments released by the European Court of Justice and European Court of First Instance. In addition, a variety of industry and business news sources were used, such as *American Metal Market*, *Chemical Marketing Reporter*, *European Business Week*, *International Cement Magazine*, *Oil and Gas Journal*, and *Wall Street Journal*. Specific sources are available from the authors upon request.

Treasury-bill rate: Annual U.S. Treasury-bill, 3-month maturity, secondary market rates are from the Federal Reserve Board's website at:

http://www.federalreserve.gov/RELEASES/h15/data/Annual_Dec/H15_TB_M3.txt

GDP: Annual world and U.S. GDP, in real 2000 U.S. dollars, come from the U.S. Department of Agriculture website at:

http://www.ers.usda.gov/Data/macroeconomics/Data/HistoricalRealGDPValues.xls

Exchange Rate: Quarterly exchange rate data from 1971 through 2002 come from Linda Goldberg's web page on the New York Federal Reserve Bank:

http://www.ny.frb.org/research/economists/goldberg/papers.html.

From this website, we used the total manufacturing exchange rate from the "Database on Industry-Specific Exchange Rates."

Market Concentration of Consuming Industry: Each cartel's customers were identified, where possible, using lists of plaintiffs in civil damage cases against the cartel members. These plaintiff lists were compiled using docket information available on the *Westlaw* legal research database. We searched *Westlaw* for U.S. district court cases only. The primary SIC and NAICS industry codes were then obtained for each plaintiff company from Hoover's or Thomson Research. We then chose one SIC code and one NAICS code to represent the downstream industry for each cartel. The choice of the representative downstream industry was based either

on the majority of customers or the most representative customer, if there was not a clear majority. For example, the citric acid cartel members were sued by numerous buyers, representing a variety of food-related industries, but the majority of the plaintiffs were from NAICS 312111 (Soft-Drink Manufacturing). For the rubber chemicals cartel there was no clear industry majority among the suing customers, but research on the cartel revealed that their primary customers were tire manufacturers. We therefore chose NAICS 326211 (Tire Manufacturing, except Retreading) as the primary customer code. In those instances without litigation—for example, there are no U.S. civil cases against the European cement cartel in our sample—we identified the downstream industry based on other research. In the case of cement, it was clear that the main customers would be the ready-mix concrete producers (NAICS 327320). For each downstream industry we assigned HHI data published by the U.S. Department of Commerce, "Concentration Ratios in Manufacturing," Economic Census. Data for 2002 and 1997 are available at http://www.census.gov/epcd/www/concentration.html. For historical data, we used a compiled series available at:

http://www.wooster.edu/economics/archive/indconc.html.

Although 1997 and 2002 HHI data are available in both value added and value of shipments, the 1992 and earlier data from the Wooster archive are given only for value of shipments. Published data are restricted to manufacturing, and therefore the early HHI data based on SIC codes has codes starting with only 2's and 3's, while the 1997 and 2002 data only lists NAICS codes starting with 3. For each year of the cartel's lifespan we assign the HHI number in five-year intervals, ranging from 1982 through 2002, as follows: 1982 HHI is used for all observations through 1984; 1987 HHI is used for 1985-1989; 1992 HHI for 1990-1994; 1997 HHI for 1995-1999; and 2002 HHI for 2000-2002.

Firm Financial Distress: We collected data to build these ratios at the firm level from Compustat North America (Industrial Annual) for U.S. firms and Compustat Global (Industrial/Commercial) for non-U.S. firms. The first step was to locate each cartel member firm in the Compustat database and identify its Global Vantage Company key (GVKEY). For North America, data is available for each firm with a GVKEY for the full sample period 1971-2002,

but Compustat Global only contains data from 1993 – 2005.[79] An additional complication is that variables names are not consistent across the two databases. In constructing the leverage ratio we used the following data from Compustat (name of variable and "data tag" as provided by Compustat): Total Liabilities (Data 181 in Compustat North America and Data 118 in Compustat Global), Shareholders' Equity (Data 216 in Compustat North America and Data 135 in Compustat Global).[80] The interest coverage variable was calculated from Operating Income (after depreciation), Total Non-operating Income Expense, Total Depreciation, and Interest Expense. The data tags for these variables, respectively, were Data 178, 61, 14, and 15 from Compustat North America and Data 14, 16, 11, and 15 from Compustat Global.

For most of the cartels in our sample, at least one cartel member was located in the Compustat database, but there are six cartels for which no member firm could be found.[81] The number of cartels in the sample therefore drops from 72 to 56. The number of observations, however, drops further: of the 364 unique cartel member firms in our sample, only 192 have Compustat GVKEYs, so that in practice we are not able to calculate the two measures of financial distress across all members of each cartel.[82]

[79] There are six cartels for which no GVKEY exists for any cartel member firm. In addition, we lose six cartels because of lack of data before 1993. Thus, a total of twelve cartels drop from the sample when we add the financial distress measures.
[80] Busse's (2002) published paper includes two typographical errors in Table 1, where the definitions of these variables are summarized. We use corrected definitions provided by Busse.
[81] These cartels are beer (Luxembourg), marine transportation services, plastic dinnerware, stamp auctions, tampico fiber, and zinc phosphate.
[82] Twelve of the 364 firms are actually subsidiaries of parent companies that were also indicted for price-fixing, either in the same cartel or a different one.

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FIGURE 1

DURATION OF INTERNATIONAL CARTELS

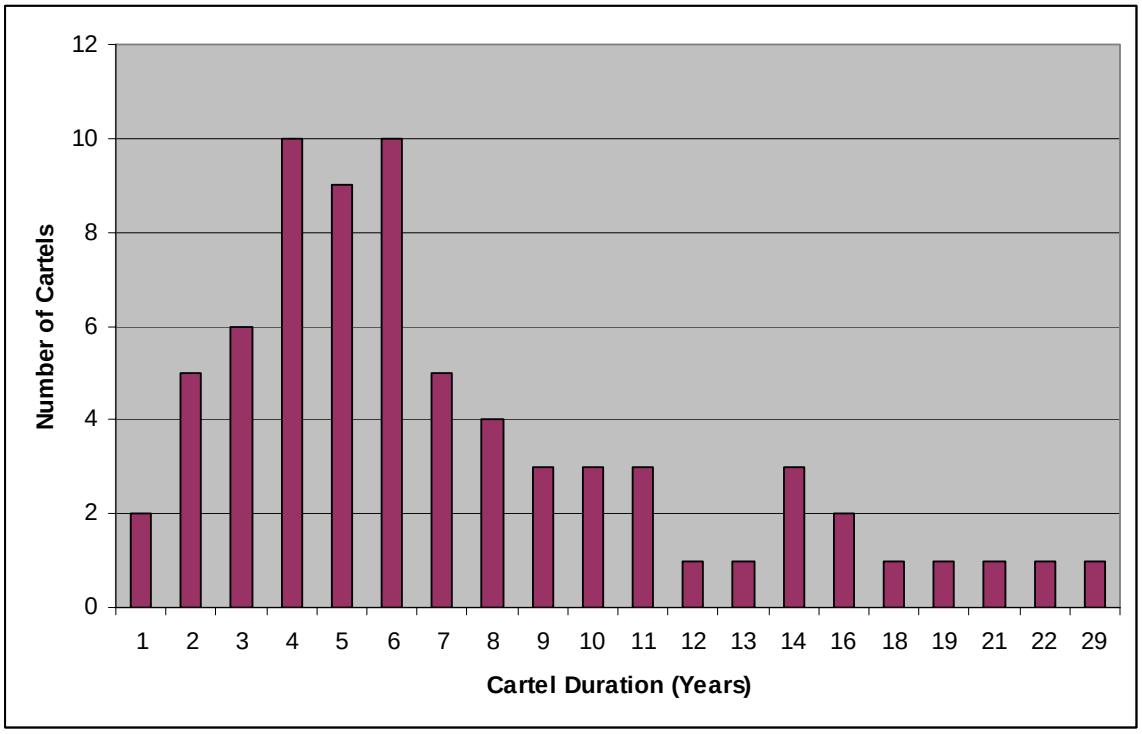

FIGURE 2

PROBABILITY OF SURVIVAL

FULL SAMPLE

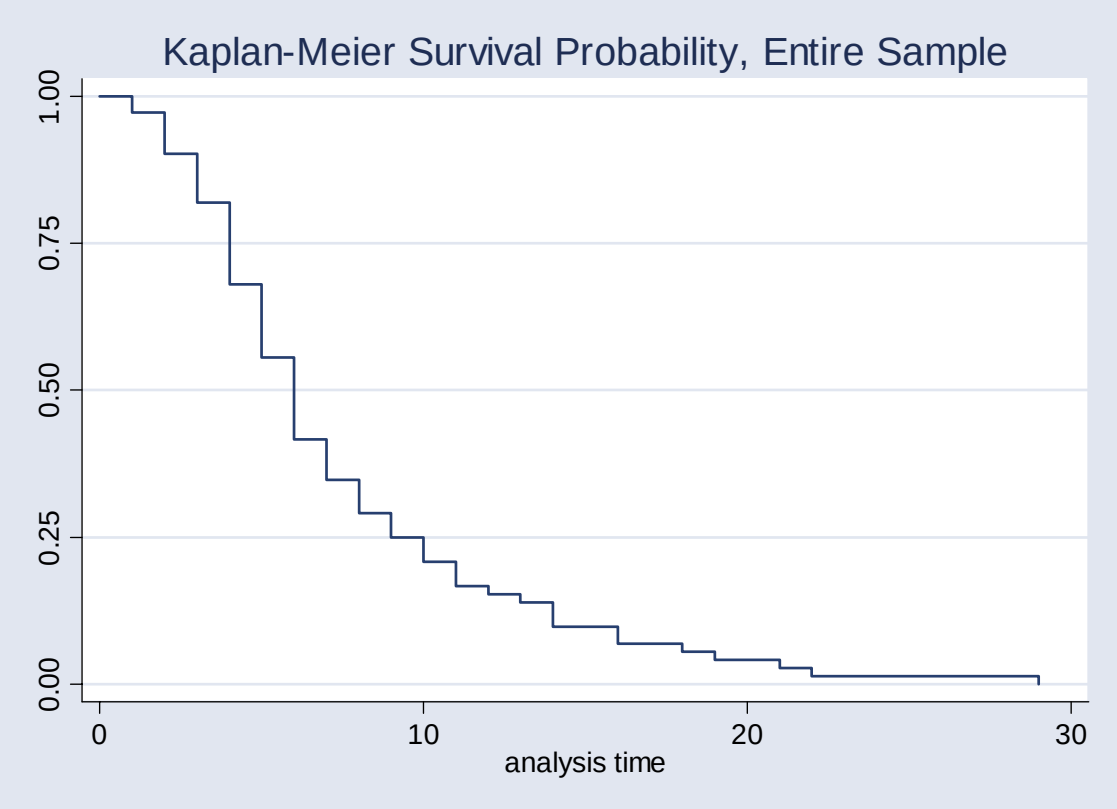

FIGURE 3

PROBABILITY OF SURVIVAL

COMPARISON OF CARTELS BY NUMBER OF MEMBERS

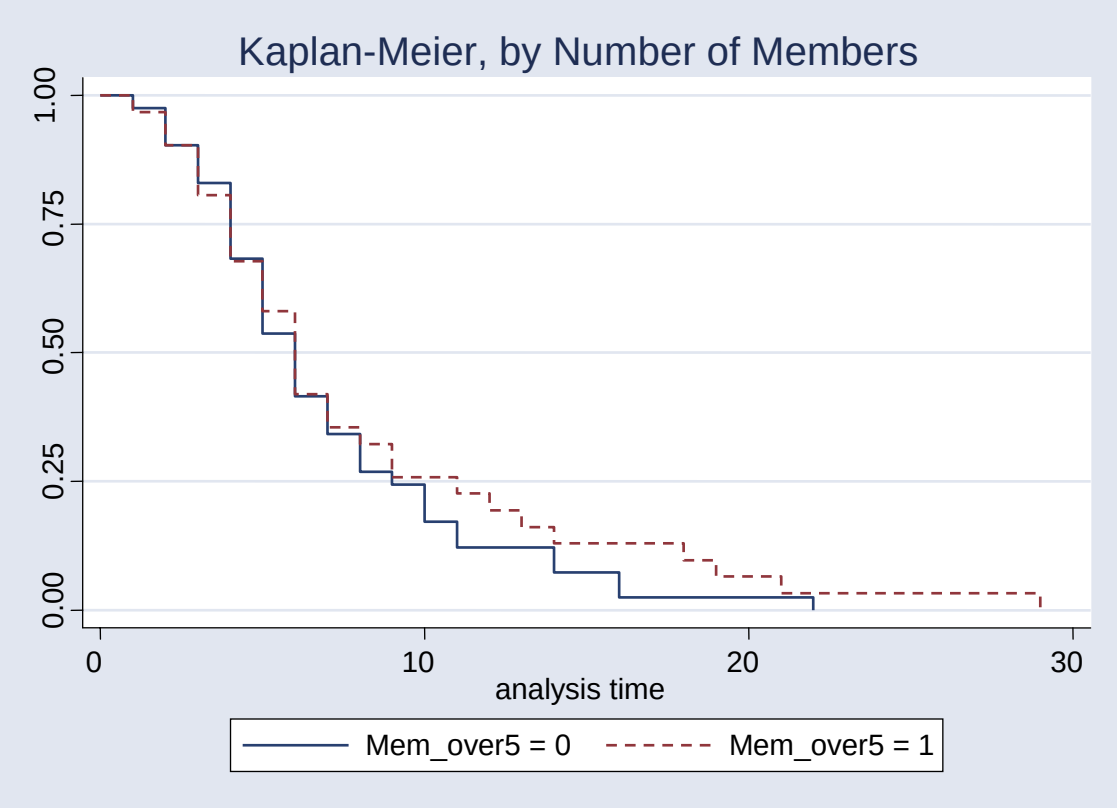

FIGURE 4

PROBABILITY OF SURVIVAL

COMPARISON OF CARTELS BY ORGANIZATIONAL COMPLEXITY

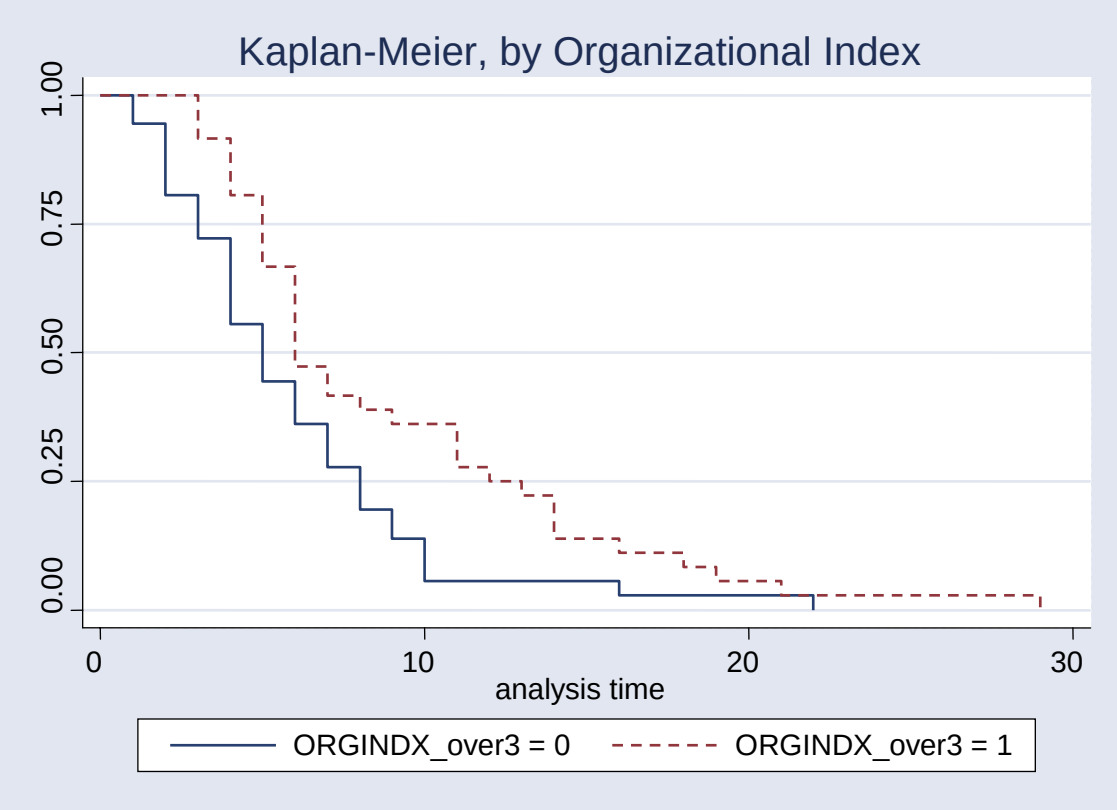

FIGURE 5

PROBABILITY OF SURVIVAL

COMPARISON OF CARTELS BY CAUSE OF CARTEL BREAKUP

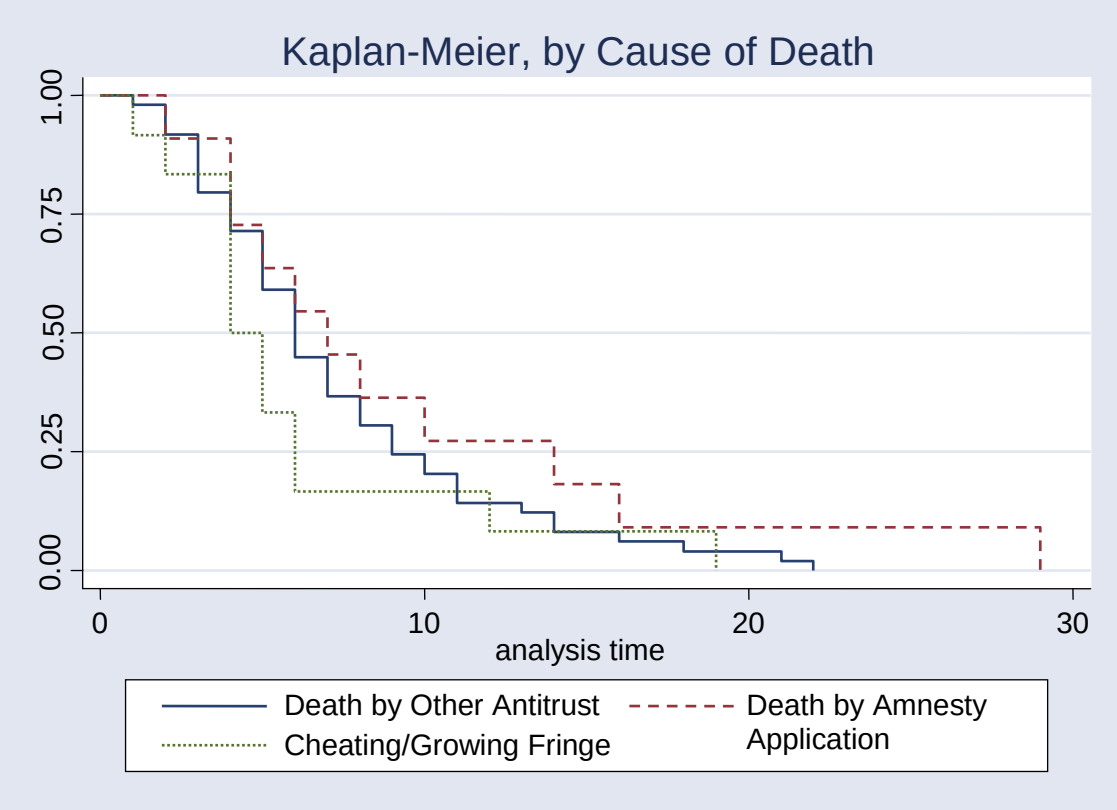

TABLE 1

SECTORAL COMPOSITION OF CONTEMPORARY INTERNATIONAL CARTELS

Industry	Percentage[a]
Chemicals	42%
Other Manufacturing	38%
Water Transport	14%
Construction	4%
Services	3%

[a] Percentages are based on a simple count of the number of cartels and are not weighted by the value of their output. The total sums to 101% due to rounding.

TABLE 2

CARTEL DURATION: COMPARISON TO PREVIOUS STUDIES

		Other International Studies			*U.S. Studies*	
Duration	*Contemporary International Cartels*	*Eckbo*[a]	*Griffin*[b]	*Suslow*[c]	*Posner*[d]	*Gallo et al.*[e]
Mean (years)	7.5	5.3	7.3	8.3	7.5	5.4
Standard deviation	5.4		6.3	6.2		
Range	1 – 29	1 –18	1 – 29	1 – 13		
% <5 years	32%			40%		
% > 10 years	21%			37%		

Notes:

[a] Eckbo (1976) covers 51 international agreements from the late 1800s through the 1960s. We calculate an average duration for the cartels in Eckbo's study. In the original work, he reports separate averages for different sub-samples.

[b] Griffin (1989) samples 54 international cartels from 1888 to 1984.

[c] Suslow (2005) samples 71 international cartel episodes in 45 industries between 1920 and 1939. The mean duration of the 28 cartel episodes not censored by World War II is 3.7 years with a standard deviation of 3 years.

[d] Posner (1970) examines all 989 Department of Justice horizontal price fixing cases from 1890 to 1969, but he reports average duration and related statistics only for cases from 1950 to 1969.

[e] Gallo et al. (2000) study 688 cases involving horizontal per se violations from 1955 to 1997.

TABLE 3

CARTEL ORGANIZATION: COMPARISON TO U.S. STUDIES

	Contemporary International Cartels	*Hay & Kelley* [b]	*Fraas & Greer*	*Posner*	*Gallo et al.*
Market Allocation[a]	81%	35%	26%	26%	27%
Bid Rigging	22%	29%	19%	14%	30%
Distributor Involvement	14%				
Terms & Conditions of Sales Set	47%	14%	5%	14%	
Product Standardization	6%				
Monitoring	72%				
Hierarchy	39%				
Trade Association Involvement	29%	29%	36%	44%	23%
Compensation Rules	28%			4% ("system of fines & audits")	
Disciplinary or Coercive Practices; Exclusion	39%	5%	12%		

Notes:

[a] Market allocation includes use of production quotas, division of markets, division of territories, and allocation of customers.

[b] Hay and Kelley (1974) sample includes 65 DOJ convictions for horizontal price fixing between 1963 and 1972. Not all industry characteristics were available for each case. For example, trade association information is available in 62 cases and concentration data in only 50 cases. In calculating the mean of their sample, they exclude four cases with 50 or more conspirators.

TABLE 4

VARIABLE DEFINITIONS AND DESCRIPTIVE STATISTICS

Number of Cartels = 72 unless otherwise stated

Variable Name	Definition	Min	Max	Mean	Standard Deviation
MEM_OVER5	1 if cartel has more than five members	0	1	0.43	0.5
MINC4 (48 cartels)	Minimum four-firm concentration ratio	40	100	78.67	18.4
CUSTCONC (44 cartels)	HHI index for cartel's primary consuming industry	25	2662.4	665.23	704.97
ORGINDX	Sum of dummy variables describing cartel organization (the 11 variables defined immediately below)	0	11	3.76	2.06
BIDRIGORG	1 if bids were rigged	0	1	0.22	0.42
MKTALLOCORG	1 if shares, regions, or customers were explicitly assigned to cartel members	0	1	0.81	0.40
STDIZEORG	1 if cartel standardized product characteristics	0	1	0.06	0.23
OTHERTERMSORG	1 if cartel set terms other than price (i.e., limiting discounts or terms of sale)	0	1	0.47	0.50
DISTNORG	1 if cartel included distributors or vertically integrated producer/distributor firms	0	1	0.14	0.35
TAORG	1 if trade association involved	0	1	0.29	0.46
MONITORORG	1 if sales information exchanged for monitoring purposes	0	1	0.72	0.45
DISCIPLINORG	1 if retaliatory action taken following cheating	0	1	0.13	0.33
COMPENSORG	1 if members agreed to a compensation scheme	0	1	0.28	0.45
EXCLUSORG	1 if cartel took exclusionary action against non-members	0	1	0.26	0.44
HIERARCHORG	1 if multiple levels of organizational hierarchy existed within cartel	0	1	0.39	0.49
CHEATORG	Sum of DISCIPLINORG and COMPENSORG	0	2	0.40	0.60
CHEM	1 if cartel in chemicals sector	0	1	0.42	0.50
MTL&MINRL	1 if cartel in metals or minerals sector	0	1	0.18	0.39
OTHMFG	1 if cartel in other manufacturing sector	0	1	0.19	0.40

NONMFG	1 if cartel in non-manufacturing sector	0	1	0.21	0.41
INTCOVERAGE (56 cartels)	Interest coverage ratio for cartel member firms	-6.13	16.19	4.24	3.66
INTCOVERAGE<1 (56 cartels)	1 if INTCOVERAGE is less than 1	0	1	0.18	0.39
LEVRATIO (56 cartels)	Financial leverage ratio for cartel member firms	0.54	1.25	0.77	0.14
T-BILL (32 annual observations)	Annual average rate on U.S. Treasury bills, 3-month maturity	1.6	14.0	6.38	2.66
POS_HP (32 annual observations)	Level of gap between GDP and trend (using HP filter) if gap is positive ($ billions)	0	377.5	79.92	119.70
NEG_HP (32 annual observations)	Level of gap between GDP and trend (using HP filter) if gap is negative ($ billions)	-357.69	0	-70.96	100.36
XER_SHOCK (32 annual observations)	Absolute value of the difference between current and lagged exchange rate index value	0.1	12.5	4.20	3.33

TABLE 5

CAUSES OF CARTEL BREAKUP

Cause of Breakup	Number of cartels	Average Duration (years)
Government-Initiated Breakup Triggered By:		
Amnesty application	11	9.5
Follow-on investigation	13	8.2
Customer complaint	8	5.3
Other sources (including whistleblowers)	28	7.6
Other Breakup		
Cheating	2	1.5
Growing fringe	7	6.4
Unknown Cause of Breakup	3	8.0
Total	*72*	*7.5*

TABLE 6

PROPORTIONAL HAZARDS MODEL

Full Sample of 72 Cartels

Variable	Model 1 (POS_HP and NEG_HP)	Model 2 (NEG_HP)	Model 3 (ORGINDX and sector dummies)
	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)
MKTALLOCORG	0.31**	0.31**	
	(-3.34)	(-3.30)	
MONITORORG	1.27	1.26	
	(0.76)	(0.74)	
HIERARCHORG	0.86	0.86	
	(-0.50)	(-0.51)	
CHEATORG	0.73	0.73	
	(-1.43)	(-1.39)	
ORGINDX			0.88*
			(-1.75)
MEM_OVER5	1.28	1.30	1.37
	(0.95)	(1.01)	(1.10)
T-BILL	0.63**	0.61**	0.58**
	(-3.16)	(-3.66)	(-4.04)
POS_HP	0.998		
	(-0.90)		
NEG_HP	1.01**	1.01**	1.01**
	(3.02)	(2.94)	(3.05)
XER_SHOCK	1.03	1.02	1.03
	(0.69)	(0.58)	(0.66)
CHEM			0.67
			(-1.21)
MTL&MINRL			0.79
			(-0.55)
NONMFG			0.82
			(-0.49)
Number of Cartels	72	72	72
Number of Obs.	540	540	540
Log likelihood	-223.8	-224.3	-228.9
Likelihood ratio χ^2	39.97	39.12	29.84
	(df=9)	(df=8)	(df=8)

*(**) The coefficient is significantly different from 1 for a 10% (5%) two-tail test.

TABLE 7

PROPORTIONAL HAZARDS MODEL

Adding producer and consumer concentration and financial distress variables

Variable	Model 4 (producer concentration)	Model 5 (consumer concentration)	Model 6 (financial distress measures)
	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)
ORGINDX	0.78** (-2.53)	0.79** (-1.98)	0.91 (-1.11)
MEM_OVER5	2.34** (2.08)	1.65 (1.23)	1.14 (0.37)
MINC4	1.00 (-0.00)		
T-BILL	0.60** (-2.76)	0.56** (-2.87)	0.81 (-0.90)
NEG_HP	1.01** (2.18)	1.01** (2.14)	1.00 (-0.05)
XER_SHOCK	1.06 (1.00)	1.04 (0.65)	1.05 (1.00)
CUSTCONC		1.00 (0.01)	
INTCOVERAGE<1			1.52 (1.04)
LEVRATIO			3.56 (1.49)
Number of Cartels	48	44	56
Number of Obs.	350	330	241
Log likelihood	-135.4	-119.9	-148.1
Likelihood ratio χ^2	17.87 (df=6)	16.86 (df=6)	8.76 (df=7)

*(**) The coefficient is significantly different from 1 for a 10% (5%) two-tail test.

TABLE 8

COMPETING HAZARDS MODEL BY CAUSE OF BREAKUP

Variable	Model 7 Breakup Due to Other Antitrust Investigation (not triggered by amnesty application)	Model 8 Breakup Due to Amnesty Application, Cheating, or Growing Fringe
	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)
ORGINDX	0.86* (-1.67)	0.89 (-0.82)
MEM_OVER5	1.28 (0.80)	0.74 (-0.60)
T-BILL		0.81 (-1.09)
NEG_HP		1.00 (0.73)
XER_SHOCK		0.89 (-1.07)
Number of Cartel Failures	49	23
Number of Obs.	540	540
Log likelihood	-164.8	-74.4
Likelihood ratio χ^2	2.81 (df=2)	6.50 (df=5)

*(**) The coefficient is significantly different from 1 for a 10% (5%) two-tail test.