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Determinants of Cartel Duration and the Role of Cartel Organization

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ABSTRACT

Previous cross-section research has treated cartel organization as a black box – acknowledging its importance but unable to measure it. We introduce a new dataset that quantifies the range of cartel organizational techniques, drawing on the unusually rich and detailed descriptions of recently prosecuted international cartels active in a wide variety of global markets. Estimating a proportional hazards model with competing risks, we are able to distinguish those factors which increase the risk that cartels will be broken up by exogenous antitrust intervention and those that affect the probability that the cartel will break up for economic reasons, such as defection, dissension or entry. The probability of cartel death from any cause increased significantly after 1995 – we call this the Whitacre effect – when competition authorities significantly increased their enforcement activities toward international cartels. This changed the calculus for member firms and provided competition authorities with a wealth of new evidence of cartel activities. We find that cartels that relied on the active involvement of a trade association were significantly more likely to be broken up by authorities. Cartels that used market allocation schemes – assigning customers or countries – were less likely to be caught. Cartels that experienced cheating by members and punished members for that activity were also less likely to be caught. It may be that these "punishments" resemble competition to antitrust authorities. Neither the number of members or the concentration of the industry – even when "high" concentration was defined as having a global C4 of over 75%, which one might expect would capture the attention of competition authorities – had any effect on the likelihood that a cartel was broken up by exogenous antitrust intervention. Except for the "Whitacre Effect," the determinants of "natural" death differed from the causes of "death by antitrust." Cartels that relied on trade associations were less likely to die a "natural" death. Cartels that compensated one another when realized outcomes did not meet agreed targets were significantly more likely to endure. Those that suffered from cheating and retaliation were more likely to break up. Market discount factors, such as short term interest rates, had no effect cartel stability, but firm-specific measures of financial distress significantly increased the likelihood of "natural" death.

I. INTRODUCTION

Economics identifies uncertainty as the primary cause of cartel instability.[1] The lure of collusive profits, however, provides firms with a strong incentive to reduce that uncertainty. The first response of many cartels to imperfect or noisy information is not to punish fellow cartel members or dissolve the cartel, but to create new rules, including governance and compensation systems that raise the quality and credibility of information and better align individual firm incentives with those of the group. Cartels that endure are cartels that manage to do exactly this.

Previous cross-section research has treated cartel organization as a black box – acknowledging its importance but unable to measure it. In this paper we introduce a new dataset that quantifies cartel organizational techniques. We have created this dataset by drawing on the unusually rich and detailed descriptions of recently prosecuted international cartels active in a wide variety of global markets. We show that cartels construct internal mechanisms to reduce uncertainty and increase the observability of members' actions. In addition, they create systems of rewards and punishments to enforce desired behavior. Finally, since it is clearly true that the threat to a cartel's stability comes from both within and without, cartels take strategic actions to increase barriers to entry, some of which may have a lasting effect on the industry.

Genesove and Mullin's (2001) influential case study of the long-lived sugar cartel demonstrates the importance of cartel organization and the ability of cartels to renegotiate their rules and mechanisms in order to maintain a successful cartel. In their conclusion, they highlight the gap between the predictions derived from theoretical models of cartel stability and the experience of the sugar cartel. Others, such as Cabral (2005) and Porter (2005) also recognize the lack of insight that existing theory provides to our understanding of the relationship between cartel organization, cartel communication, and cartel stability. Those economists who believe that sophisticated, long-lived cartels are possible, read Genesove and Mullin and say, "of course." Those more prone to believe that the vast majority of cartels are unstable and short-lived say, "these results are merely for one rather obscure, pre-World War II cartel." We attempt to bridge this gap.

[1] See Stigler (1964), Green and Porter (1984), and Abreu, et al (1986).

We have created measures of cartel characteristics for a sample of international cartels convicted of price fixing since 1990. We measure characteristics of the cartel agreement, including the use of monitoring, market allocation, and compensation schemes. We measure features of the cartel organization itself, such as whether it has a hierarchical structure. We also capture features of the implementation of the cartel agreement, including the use of retaliatory punishments or price wars. As far as we know, this article is the first attempt to analyze the impact of organizational factors on duration in a cross-section of contemporary cartels. Using a competing proportional hazards model, we are able to estimate the impact of different features of cartel organization as well as fluctuations in exogenous economic activity on the probability of cartel "death." Our estimates distinguish between those factors which contribute cartel death when the "cause of death" is exogenous antitrust intervention and those that contribute to cartel collapse, which we refer to as "natural death." Involvement of trade associations appears to be a double edged sword for cartels. Their involvement significantly increased the likelihood that they would be caught and broken up by the authorities. But they also appear to be very helpful at reducing uncertainty and resolving differences: trade associations significantly reduced the likelihood of "natural death." Cartels that developed systems to compensate one another when realized outcomes did not meet agreed targets – usually because realized demand differed from projected demand – lowered their probability of breakup. Those that suffered from cheating and retaliation were less likely to be caught by the authorities, but were more likely to break up on their own.

We test several hypotheses suggested by game theoretic models of collusion that have implications for the effect of demand fluctuations on cartel stability. While theoretical models quite generally predict that collusive stability is related to the members' discount rates, this has rarely if ever been tested empirically. We test for the effects of fluctuations in firm impatience, as proxied by both the market interest rate and by measures of firm-level financial distress. Of these, the extent of firm financial leverage – whether or not a firm can cover current interest payments on debt obligations – is the strongest predictor of cartel breakup. Market interest rates do not appear to have a significant impact on cartel stability. We also attempt to test various predictions regarding fluctuations in demand and cartel stability. We find that no evidence that demand fluctuations directly affect cartel stability.

We also test several hypotheses related to industry structure suggested by earlier industrial organization literature. Neither industry concentration (Bain 1951) nor the number of member firms (Selten 1973) has any consistent effect on cartel duration. Downstream customer concentration does not appear to have the destabilizing impact hypothesized by Stigler (1964).

National and international cartels face many of the same challenges, both economic and legal, and make use of similar organizational devices. There are differences, however, in the strategies employed by national and international cartels. For example, and not surprisingly, geographic market allocation rules are used much more frequently by international cartels, rather than the simple production quotas favored by domestic cartels. National barriers provide a convenient mechanism for dividing markets as well as a mechanism for monitoring violations in cartel agreements. In addition, international cartels face unique challenges posed by cultural and linguistic differences, exchange rate fluctuations, and trade preferences. International markets are, by definition, ones where there are more potential entrants, so entry deterrence is a bigger challenge to cartel stability. Each of these factors creates tensions among cartel members and potential instability for the cartel. This suggests that collusion may be especially challenging in international markets. Thus, these markets provide a rich testing ground for explanations of cartel duration.

The basic theory of cartel duration is laid out in the following section. We 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: [2]

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

where

[2] 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 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, which we refer to 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 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? One way to answer this question is to consider equilibria in which collusion does last, but in which firm behavior fluctuates. In their classic articles, Green and Porter (1984) and Porter (1983) introduced the notion of price wars as equilibrium punishments in which it appears that a collusive agreement has collapsed, but where in fact the cartel shifts to a "punishment phase" that is required to maintain incentive compatibility. These fluctuations in behavior are often observationally equivalent to cartel breakup. An alternative answer is that, while firms expect this inequality to hold when a cartel is formed, the constraint is violated by future, unanticipated shocks.[3] In that case, duration would be systematically related to the unanticipated shocks that lead to the violation of the participation constraint. In the discussion that follows, we consider hypotheses regarding the determinants of cartel duration that follow from both behavioral fluctuations in a collusive equilibrium and an analysis of shocks that might disrupt a collusive equilibrium. 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.

A. Firm Patience and Collusive Stability

One of the few broad 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, a collusive equilibrium that can be supported at a prevailing discount rate may no longer be sustainable 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.[4] Firm-level changes in the discount rate may also affect the stability of the cartel. For example, a firm's rate of time preference might change if its financing shifted 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.[5] Busse (2002) frames this as a question of how close cartel members are to bankruptcy, when they might well not have access to liquidity at the market interest rate. Fershtman and Pakes (2000) provide a full theoretical justification for the focus on bankruptcy by demonstrating that cartels are less likely to survive if one member is close to exit. They posit two reasons that the presence of a financially marginal firm may destabilize collusion: "insufficient punishment" and "predatory behavior" (Fershtman and Pakes 2000, p. 221). A firm that is likely to exit has a shorter time horizon and cannot be punished for defection. Stronger firms that expect to stay in the industry would like to speed the exit of the firm that cannot be counted on as a collusive partner, and will therefore prefer not to collude but rather will engage in predatory pricing.

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[3] 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.

[4] For example, Barsky and Kilian (2004) discuss the possibility that fluctuations in the rate of interest affected OPEC's ability to collude to raise prices.

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

Finally, lengthening the lag time between periods also increases the discount rate. Conversely, reducing the real time between periods will weaken the constraint on collusive equilibria and make collusion less fragile. The European Commission has documented attempts by several cartels to eliminate long-term contracts and credit extensions. We quantify and construct measures of each these determinants of the discount rate to examine their impact on cartel duration.

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 $x_{it}(p^{M}_{i,t}, p^{C}_{-i,t}, \theta_H)$ and $x_{it}(p^{M}_{i,t}, p^{M}_{-i,t}, \theta_L)$ 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. In Green and Porter (1984) unexpected negative shocks to demand lead to the appearance of cartel breakup. In contrast, Rotemberg and Saloner (1986) propose a model in which cartels become less effective during macroeconomic booms even though the state of demand is common knowledge.[6] Collusive prices respond to changes in demand to assure that the expected returns to cheating today remain below the expected returns from future collusion. We explicitly test for the impact of both "Green and

[6] Haltiwanger and Harrington (1991) reverse the cyclicality of prices by introducing auto-correlated shocks to demand. Bagwell and Staiger (1997) provide a further elaboration of this model by distinguishing between the impact of stochastic fluctuations in growth rates (generating a business cycle) and transitory shocks to demand.

Porter" and "Rotemberg and Saloner" type demand fluctuations on cartel stability. We allow for upturns and downturns in the business cycle to have different effects on cartel duration, and we distinguish the impact of observable and unexpected demand fluctuations.

Second, because the enactment of an "equilibrium punishment" of permanent or long-term reversion to competitive pricing is costly to firms in terms of foregone future profits, firms try to avoid making the mistake of punishing where no firm has cheated. 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 of the cartels in our sample, cartel members that sold more than expected were required to 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.[7] We expect that cartels that develop such compensation mechanisms will last longer, all else equal.

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.[8] In other cases, cartel members will agree to use a single distributor (such as a joint sales agent) to monitor all sales. [9]

One of the simplest and most common techniques that cartels use to reduce imperfect information 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

[7] Historically, cartels have handled this problem with a variety of mechanisms. For example, the bromine cartel members simply provided direct monetary compensation – from one cartel member to another – when actual sales were not allocated as contemplated by the cartel agreement (Levenstein 1997, p. 19). Direct compensation raises the risk of detection by competition authorities and is not observed in the current legal environment.

[8] We rarely observe cartels exchanging information about costs, even though the exchange of such information could, in principle, increase cartel efficiency. As noted in Athey and Bagwell (2001), exchange of such information entails costs as well as benefits to the cartel. Cartel members recognize this and rarely share information about costs. See Levenstein and Suslow (2006b) for further discussion of the content of cartel communications.

[9] 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. Bernheim and Whinston (1985) provide a game-theoretic explanation of the use of a joint distributor that focuses on the alignment of producers' incentives rather than monitoring or reducing uncertainty.

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.[10]

Finally, it is often the case that having agreed to refrain from competing on price, cartel participants try to obtain an advantage over their co-conspirators by competing 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. We measure the use of these various techniques to reduce imperfect information by the cartels in our sample and test for their effect on cartel duration.

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. Cartels will sometimes engage in strategic activities that are designed to increase barriers to entry.

[10] 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.

Cartels in our sample engage in a variety of such activities, including the refusal to license technology, strategic acquisition of entrants, and targeted price wars.[11] We measure these activities in a categorical variable which captures the extent of exclusionary behavior on the part of each cartel in the sample.

Turning to the buyer side of the market, Stigler (1964) argued that buyer size affects cartel stability. If the customers of a cartel are large relative to the size of the market, the temptation to cheat will be greater, he argued, because each firm will find it easier to "steal" a large proportion of the market from other firms. 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 that offers its customers $p^D_{i,t} = p^M_{i,t} - \varepsilon$ to capture the entire market. Alternatively, suppose that the "customers" are themselves producers, and the downstream consuming industry consists of a few large firms and a competitive fringe. The large "customers" may find it advantageous to have an upstream cartel, because they are in a position to bargain for lower prices while their smaller competitors are not. This price differential on a purchased input may give them a strategic advantage that outweighs any incentive to undermine the cartel altogether. Thus it is not clear *a priori* what the impact of buyer size or buyer concentration is on cartel stability.

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, even the most hostile antitrust authorities presumed that international cartels were largely beyond prosecution – either for diplomatic or jurisdictional reasons or simply because of the difficulty in obtaining evidence. 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. This

[11] For example, Harrington (1989) shows that cartels that are able to engage in predatory behavior in response to entry may sustain collusion without any other barriers to entry.

policy change took place in different countries over time and reflects a variety of political and economic considerations. But the precipitating even was Mark Whitacre's cooperation with the U.S. FBI in an investigation into Archers Daniels Midland, resulting in the breakup of the lysine cartel in 1995 and subsequent felony convictions of both the member firms and key executive personnel.

Almost eighty percent of the cartels in the sample ended with antitrust intervention. This might suggest that the determinants of cartel breakup are legal, not economic factors. That suggestion would be wrong. The key enforcement instrument used by competition authorities since the mid-1990s in uncovering international cartels has been the offer of full amnesty or partial leniency to the first firm that cooperates with the competition authorities by providing evidence of collusion. These policies (which we discuss in detail in the next section) alter a firm's decision to participate in a cartel. Consider the case where the antitrust authorities offer complete amnesty. Any firm that chooses to leave the cartel—knowing that its defection would induce a reversion to competition in the industry—will simultaneously apply for amnesty.[12] In this case, the decision to defect or cooperate is not altered from that implied by the participation constraint.

For example, in the wax cartel, Shell applied for leniency from the European Commission on March 17, 2005, after a February meeting at the "brightly colored four-star Hotel Madison Residenz in Hamburg [at which the cartel] was unable to come to an agreement on prices" (NYT Dec. 12, 2008). Similarly, a member of a bridge construction cartel notified the Canadian authorities of the existence of the cartel after it lost out on a bid. In the laminated tubes cartel, a member firm applied for amnesty because they wanted to enter US market which they were excluded from under the cartel agreement. In each case, the immediate, precipitating cause of the cartel breakup was antitrust intervention. But the decision to apply for amnesty is an economic one influenced by the expected profitability of the cartel compared to the profits available when freed from cartel restrictions. When a member no longer expects the cartel to be profitable, it makes sense for it to apply for amnesty. The increase in criminal enforcement and

[12] One could also consider the possibility that a firm would choose to defect "a little" hoping that this would not undermine the cartel. We do observe small violations of collusive agreements which are either tolerated or punished lightly. We do not treat minor defections as cartel breakups in our data, so this possibility does not affect the analysis of duration. This behavior does represent an important theoretical challenge to cartel modeling, as it is not consistent with equilibrium behavior in most models.

the availability of amnesty changes the calculus, but, controlling for this discrete change in incentives, the other elements of the decision to participate in a cartel remain the same.

The contrast between methionine and methylglucamine also illustrates this point. Rhone-Poulenc was caught up in the vitamins cartel and subsequently gave evidence in the methionine case, receiving amnesty. But it did not give evidence in the methylglucamine case for which it was later fined. Why would it turn in one cartel and not the other? The methionine cartel had ceased to have much effect on price as a result of Monsanto's expansion in the production of a liquid product. Monsanto refused to participate in the cartel, so the benefit to continuing the cartel was quite limited. Firms are clearly making strategic decisions about which cartels to offer up for amnesty, and they are the cartels that are failing.

Alternatively, consider the case where the authorities offer only a reduction in liability: the European Union, for example, often grants a percentage reduction in fines, and in the United States amnesty from criminal liability does not spare firms from potential civil liability. A firm considering defection must then consider an additional cost associated with the remaining potential legal liability.[13] When we observe in our data that a cartel has been broken up by an amnesty application, it must be that a cartel member that had previously found it optimal to cooperate no longer does. This could be the result of a one-time shift in enforcement policy (which we test for), but it could also be because of a change in any of the economic variables that affect 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.

III. DATA

A. Sample of Contemporary International Cartels

[13] The firm may face potential legal liability because it reports the cartel to the authorities. Alternatively, if the defecting firm does not report, other cartel members might (in which case the defecting firm would face the full fine). For a provocative and insightful discussion of the incentive effects of amnesty and leniency policies, see Spagnolo (2000). He shows that partial amnesty can actually increase 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 leniency policies that reduce, but do not entirely eliminate fines, decrease the likelihood of cartel breakup. This does not, however, change the impact of economic fluctuations on cartel stability. For a general review of work in this area, see Spagnolo (2006). See Aubert et al (2006) for a discussion of alternative designs of leniency programs and their impact on both cartel stability and firm performance.

We examine the determinants of cartel duration for 81 international cartels convicted of colluding in either the United States or the European Union (or both) since 1990.[14] Each of these cartels engaged in illegal price fixing or market division agreements, and each includes member firms from more than one country.[15] Under current law, virtually all such agreements are illegal in these two jurisdictions.[16] Although these cartels are international in membership, they may or may not have a global reach. Many 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. While all the cartels in our sample were active after 1990, some began operations years before. The oldest cartel in our sample, organic peroxides, began in 1971. The last of our cartels broke down in 2007 (marine hose). For 79 of these 81 cartels, we have been able to assemble information on the cause of cartel breakup. Our sample falls slightly when we examine certain characteristics of the market, such as industry concentration, or firm-level measures that are not available for privately held firms, such as financial condition. Of these 81 prosecutions, 21 were prosecuted in both jurisdictions; 19 were U.S.-only cases and 41 were EU-only cases.

Cartels affect a remarkably broad range of industrial sectors. Most of the cartels in our sample are in intermediate manufactured goods and services. Forty percent of the cartels in our sample are in chemicals, especially food additives (Table 1). Another quarter of the cartels in our sample are in a variety of other manufacturing industries, 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. But cartels are not restricted to manufacturing. Cartels were found in specialized services, such as fine arts auctions, and water transportation, including ocean shipping, various ferrying operations, and a

[14] 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.

[15] 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.

[16] There are exceptions for certain industries, such as agriculture, 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. See Levenstein and Suslow (2005) for a discussion of the prevalence of antitrust exemptions for export activity. For a discussion of the economic impact of such exemptions, see Levenstein and Suslow (2007).

variety of specialized oil and chemical transport. The only sector that does not appear in this sample is final consumer goods.

The distribution of cartel duration in this sample is skewed with a long right hand tail (Figure 1). The average duration of cartels in our sample was approximately 8.1 years, with a standard deviation of 5.8 years (Table 2). The median lifespan was 7 years. The probability of a cartel's surviving past time *t* is shown in Figure 2, using a non-parametric estimate of the Kaplan-Meier (KM) survivor function. 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 beyond 5 years have a reasonable probability of lasting a very long time. There were long-lived cartels, for example, in sorbates, stamp auctions, and organic peroxides. At the other extreme, just under ten percent of the cartels in our sample lasted two years or less. The shortest-lived cartel in our sample, the cross-Channel ferry operators' cartel, formed in October 1992 and dissolved in December 1992 after a complaint from the Freight Transport Association representing British exporters.[17]

Average cartel duration does not appear to have changed substantially over the past century (Table 2). Suslow (2005) examines 71 international cartels active before World War II and finds an average duration of 8.3 years.[18] Eckbo (1976) examines a sample of 52 international cartels spanning most of the 19th and the first half of the 20th centuries, and finds an average duration of 5.3 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.[19] As Stigler (1964) observed, 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.

[17] Strain (1995).
[18] 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).
[19] 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.

Most of the cartels in our sample had a small number of member firms. The median number of members is 5, and the mean is 7.1. The number of members 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 by whether the cartel had more than five members. Cartels with more members appear to last slightly longer than cartels with fewer members. This is counter-intuitive, but appears to reflect the ability of cartels to overcome both organizational and incentive problems arising from increasing numbers. Figure 4 provides a similar picture, showing the probability of survival for cartels with and without trade association involvement. Again, the distribution of the two curves is very similar, but as we will see below, once one controls for both number of members and the cause of death, we can see that the active involvement of a trade association facilitates cartel durability.

These contemporary international cartels occur predominantly in very highly concentrated industries. The average four-firm concentration ratio (C4) for our sample is 76 percent.[20] Two-thirds 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.[21] We observe even more extreme concentration levels for many cases: 44 of the cartels were in industries with a C4 of at least 75 percent.[22] Many empirical studies of international cartels measure the *cartel's* market share.[23] 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 cartel market share.

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[20] Our concentration measure is based on a subsample of 57 cartels for which we have market share data.

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

[22] Forty-four is a lower bound, as there were some industries for which we were not able to obtain reliable concentration measures. 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.

[23] 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, while 17 percent (9 cartels) have market shares of at least 90 percent. Suslow (2005, p. 12) reports that, for 39 of the 71 cartels in the sample with market share data, the average cartel had at least fifty percent of the market. In their 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."

In some cases, existing concentration ratios reflect the actions that cartels have taken to limit entry into their markets (Table 3). Over one-third 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.[24] In 1992, members of the electrical carbon cartel refused to supply any graphite to an East German competitor that had entered the international market after unification and "systematically undercut… it with all customers, so that it would not be able to sell anywhere."[25] In actions reminiscent of John D. Rockefeller and Standard Oil, the organic peroxide producers "agreed that each of them would purchase [a] competitor. Akzo agreed to acquire … Nobel and Enichem. Laporte would purchase Aztec."[26] On the other hand, cartels may *reduce* concentration if their profits allow more firms to remain in the industry than would be sustainable in a more competitive environment (Sutton 1991, 1998 and Symeonidis 2002). Finally, one might expect that explicit conspiracies to fix prices would be redundant for firms in highly concentrated industries. The high concentration ratios in our sample may therefore reflect our selection criteria: we are sampling cartels who got caught. Firms in highly concentrated industries with keener leadership may be able to find ways to avoid competition without resorting to explicit collusion – and the threat of prosecution.

B. Organizational Characteristics

In many instances, our model of collusion suggests that cartel duration is influenced both by variables exogenous to the cartel and by the self-conscious activities of the cartel. 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. Many previous studies of cartels have assumed that understanding the fundamental determinants of cartel duration requires only better measures of exogenous structural conditions. MacKie-Mason and Pindyck (1987) make a strong argument for this position in their study of the mercury cartel. They argue that structural factors, such as barriers to entry, are more important than organizational ones to cartel success.

[24] For the steel beam cartel, see Goldsmith and du Bois (1994, p.3). For graphite electrodes, see U.S. Department of Justice (1998), where one of the charges listed is that the conspirators "agreed to restrict non-conspirator companies' access to certain graphite electrode manufacturing technology."

[25] European Commission Decision of 3 December 2003, Case C.38.359 – Electrical and Mechanical Carbon and Graphite Products, par. 157.

[26] European Commission Decision of 10 December 2003, Case COMP/E-2/37.857 – Organic Peroxides, par. 271. See Tarbell (1950) for a detailed description of Standard Oil's acquisitions of its competitors.

In the absence of market power, organizational innovations were able to preserve the formal structure of the cartel, but not its ability to increase price. But cartels do not simply accept the deck that is dealt: they shuffle. As Genesove and Mullin (2001) have shown, cartels put tremendous energy into organizational innovations that can, at least in some cases, make cartels more successful.[27] In our empirical analysis, we disentangle these issues by using proxies of exogenous determinants of cartel stability *and* measures of activities the cartel itself engaged in to affect cartel stability.

Several previous cross-sectional studies have characterized mechanisms that cartels use to create barriers to entry and prevent cheating, but have yet to establish a systematic relationship between organizational variables and cartel duration or success.[28] In part, this is because cartels differ along many dimensions which affect their ability to develop sophisticated cartel organizations: the level of trust in the industry, differences in their experience implementing cartel agreements, and differences in the personalities of the managers involved.[29] In addition, this reflects insufficient information on the organizational mechanisms employed by cartels. Our data allows us to create detailed measures of organization, to which we now turn.

1. Organizational Mechanisms

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

[27] Dye and Sicotte (2006) examine in detail the 1931 negotiations of the international sugar cartel, demonstrating the importance of conceiving of cartels as governance mechanisms implementing and renegotiating incomplete contracts.

[28] Of course, 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. See Suslow (2005) and Griffin (1989) for analyses of the impact of cartel organization on early 20th century cartels. See Levenstein and Suslow (2006a) for a discussion of these and other cross-section studies of cartel duration. Deltas, et al (1999) examine the complexity and completeness of fifty pre-World War I shipping conferences. They find that larger firms and firms with more multi-market contact are more likely to regulate non-price competition. But they do not address the relationship between the complexity of cartel agreements and either cartel duration or cartel success more generally, so their results are not comparable to those presented here.

[29] 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

agreement.[30] 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.[31] National boundaries also provide focal points and institutionally-supported market divisions (supported by differences in language, currency, and distribution networks) that can facilitate collusion. 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 agreeing to rotate bids among cartel participants. Just over one-fifth of the cartels in our sample engaged in such behavior. 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 government supply contracts—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."[32]

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

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(1993) argue that organizational issues were critical to the success of the electrical equipment conspiracies of the 1950s.

[30] 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. Porter (2005) notes that a "simple solution to the cartel problem assigns customer or territories to the participants" (p. 157). An efficient solution to the problem of assigning markets or output levels would distribute output quotas on the basis of the comparative advantage of different producers. Athey and Bagwell (2001), for example, describe an equilibrium in which an efficient collusive mechanism is achieved by having high cost producers reduce output.

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

[32] U.S. Department of Justice (2002). See Kwoka (1997) for another example of a bid-rigging cartel using a post-auction redistribution mechanism.

having all sales funneled through a single central sales organization.[33] 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 about one-sixth 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 44 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 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.[34]

A smaller proportion of cartels (seven 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…"[35] 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."[36] These provisions limit the other dimensions on which member firms might compete for customers. 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.

[33] For example, Alcoa and the European Aluminum Association essentially eliminated competition between themselves in the interwar Japanese market by agreeing to use a single distributor, a firm controlled by the Alcoa's Canadian subsidiary (Bertilorenzi 2009). Similarly, Dow and the German Bromkonvention agreed to rely on a joint distributor in 1908, after the German's conceded a share of the European market to the upstart American producer (Levenstein 1993).

[34] For details on the beer cartel, see European Commission Decision of 5 December 2001, Case IV/37.614/F3 PO – Interbrew and Alken-Maes, par. 44, 47; for the fine arts auction, see U.S. Department of Justice (2000) and European Commission (2002).

[35] United States of America v. Carbone of America Industries Corp. and Michel Coniglio; Criminal No. 00-129, March 13, 2000, p. 5.

[36] European Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 2.

2. Preventing Cheating

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.

Despite rapid technological change in communications in the late twentieth century, the cartels in this sample still rely heavily on direct, face-to-face meetings and negotiations. They do so to overcome the ever present threat of cheating by building trust; trust is undermined not only by the incentive to cheat but also by the illegal nature of the activity.[37] Over 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 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."[38] 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...."[39]

Similarly, Samsung encouraged its DRAM sales representatives, in an internal Power Point slide presentation titled "Request to Field" to "collect customer & competitive information and

[37] The relationship between cartel stability and trust is discussed in detail in Leslie (2004). Levenstein and Suslow (2006b) gives a more detailed discussion of communication among a subsample of the cartels considered here.
[38] European Commission Decision of 16 December 2003, Case C.38.240 – Industrial Tubes, par. 85, 198.
[39] European Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 191.

share them on a timely basis" (par 157, Amended Civil California complaint). Customers in a civil suit against members of the DRAM cartels claimed that,

> in the last month before the DOJ subpoenaed some Defendants, the Defendants found it too bothersome to email and call each other, and so set up a "listserv" where everyone could share information with the whole group: On May 15, 2002, an Infineon employee calling himself "Supplier 2002 uk" at supplier2002uk@hotmail.com sent an email titled "Supplier Group on Yahoo" to two Micron employees, two Infineon employees, three Samsung employees, two Elpida employees, one Nanya employee, and five Hitachi employees. The email sender states that the "point of this group is to get the supplier to share information rather than rely on [what] the customer tell[s] us." The email sender advises the participants to set up Hotmail or Yahoo email addresses to ensure anonymity. (par 161)

In other cases, cartels turned to third parties to collect, review, and sometimes aggregate data for use by individual cartel members.[40] 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."[41] 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.[42]

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. Over 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 to set

[40] Aoyagi (2005) provides an interesting discussion of the role of third parties in facilitating collusion. He posits that they receive private reports from cartel members to verify that they have implemented agreed upon actions, and use that private information to coordinate firm behavior by giving "secret instructions to players" (p. 456). The third parties discussed here engage in the first action – collecting private information – but do not play the role of coordinator. It is more useful to think of their role as reducing uncertainty or private information, rather than coordinating the play of cartel members.

[41] European Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 33.

[42] European Commission Decision of 13 July 1994, Case IV/C/33.833 – Cartonboard, par. 27, 61-62.

overall goals for the cartel. These were followed by "technical meetings" where the details of implementation were discussed:

> 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.[43]

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 strategy, quotas and prices, and lower level managers met more frequently to monitor compliance at a global and regional level.[44] 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."[45] The copper plumbing cartel distinguished between the "elephant meetings" of top level managers and the "sweepers meetings" of operational managers.[46] Similarly, the citric acid cartel had its "masters" and "sherpas," and the steel heating pipes cartel its "popes."[47]

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 a significant difference. Of the twenty-one cartels in our sample with trade association involvement, not one involved a U.S. trade association. Fourteen cases involve pre-existing European trade associations whose activities in facilitating collusion probably pre-date 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

[43] Van Barlingen (2004, p. 44).
[44] European Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 172-188.
[45] European Commission (2004).
[46] *Ibid*.
[47] Eichenwald (1997); European Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 31.

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 here to distinguish between cheating and random fluctuations in demand. Cartels do not want to disrupt collusion – reducing 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 excessive deviations from assigned quotas, as that would simply reward cheating and undermine the cartel.

As a result, many cartels – a third 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. Therefore, 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.[48]

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

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

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 19 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 percent. 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."[49] 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."[50]

Combining this "punishments" category with exclusionary actions (to prevent entry or fringe growth) 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. Forty-three percent of the cartels in our sample used some form of disciplinary or exclusionary tactics.[51] 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 European competition authorities.

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. In our empirical analysis, we rely heavily on descriptions of cartel activities provided by antitrust authorities.

[49] European Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Pre-insulated Pipe Cartel, par. 52.
[50] Acharya (1999).
[51] 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 analyze separately the implementation of punishments.

This has several implications for our measure of cartel duration. First, the start date for a cartel as coded in our dataset reflects the information available to the enforcement authorities. In many cases the authorities (or the customers) suspect that the cartel had earlier beginnings, but there is insufficient evidence to document cartel formation in the earlier period. Different firms may join a cartel at different dates, and sometimes cartels begin in one region and expand to other areas. In order to at least partially capture these nuances, we take the "birth" of the cartel to be the first known agreement between any two members of the cartel. We do not estimate the determinants of cartel birth, but a cartel is only at risk of dying after it has been born.

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.[52]

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.

We have coded "cause of death" for each of the cartels in the sample (Table 5). At the broadest level, we distinguish 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 clarify the distinctions we make

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

in coding "cause of death," we briefly review 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 in its earlier years 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 offers evidence of a cartel and agrees to cooperate in its investigation.[53] The number of corporations coming forward and seeking amnesty rose in the early 1990s from roughly one per year to one per month.[54] This trend has continued to accelerate: by 2003, the DOJ was receiving roughly two amnesty applications per month.[55] The percentage of foreign defendants has also risen dramatically.[56]

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."[57] Some companies will simultaneously apply to multiple jurisdictions for amnesty, as Christie's art auction house did in 2000.[58] As shown in Table 5, there are seventeen cartels in our sample that ended due to an application for amnesty; these cartels lasted an average of 10.3 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 8.8 years. There are formal and

[53] The firm must come forward voluntarily and prior to the commencement of an antitrust investigation. See Department of Justice Antitrust Division, *Leniency Policy Documents*, http://www.usdoj.gov/atr/public/criminal.htm (linking to the current corporate and individual amnesty policies of the U.S. Department of Justice).

[54] Bingaman (1996).

[55] Pate (2003) 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).

[56] 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).

[57] European Commission Leniency Policy, 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 also, European Commission, Directorate-General for Competition, 32nd Report on Competition Policy, 2002, p. 18 (http://ec.europa.eu/comm/competition/annual_reports/2002/report_short_en.pdf).

[58] According to Osborne (2002), "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."

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 the authorities.[59] 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. For example, Interbrew informed the European Commission about the private label beer cartel while it was being investigated regarding a separate beer cartel.[60] 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.[61]

Since the DOJ rarely publicizes the identity of firms receiving Amnesty Plus, we have in most cases had to infer whether a cartel investigation followed directly from an earlier investigation. 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 the timing of follow-on confessions will differ from those offered under a voluntary amnesty plan. Table 5 reports duration for cartels broken up by unprompted amnesty applications separately from those that result from amnesty plus and other follow-on investigations. When we estimate the determinants of breakup by cause of death, we make a similar distinction.

Some government prosecutions are instigated not by producers, but by customers. In our sample there are seven cases where a customer complaint triggered an investigation and the eventual breakup of the cartel. These cartels had an average duration of 4 years. The first vitamin cartel to be investigated (vitamin E) falls into this category, as do the cross-channel ferry

[59] The amnesty plus program is summarized in Hammond (2004). There is also a policy known as "affirmative amnesty" where 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.

[60] European Commission (2001).

[61] European 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" (European Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 149).

operators cartel, graphite electrodes, thermal fax paper, stainless steel, and several shipping cartels.

Finally, the last category of government breakup of cartels comes from those cases where an agency investigation arises from some other source of information (excluding amnesty applications, follow-on investigations, and customer complaints). This is in fact the modal cause of breakup: 29 of 81 cartels fall into this category, with average duration of 8.2 years. In the chemical tankers, ferrosilicon, citric acid and lysine cases, for example, a whistleblower triggered the investigation.[62] In the pre-insulated pipe cartel, a competitor who had been hounded by the cartel complained to the EC. [63]

Cartels that applied for amnesty, prior to any known antitrust investigation of their firm, were relatively long-lasting cartels (with an average duration of 10.3 years). Harrington (2006) argues that changes in antitrust policy will lead to a change in the observed distribution of cartel age and in the distribution of those caught by the government. He finds that "…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. Even those cartels 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 8.8 years). Although we are not able to test these predictions formally, Figure 9 shows the KM survival function for cartels in three different categories: those broken up by amnesty applications (confession), those broken up by other antitrust investigations, and those broken up by cheating or competition from a growing fringe. For most of the distribution, those applying for amnesty are the longest lived, followed

[62] 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.

[63] The pre-insulated pipe cartel made numerous attempts push this competitor, 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." European Commission Decision of 21 October 1998, Case No IV/35.691/E-4 – Preinsulated Pipe Cartel, par. 20.

by those caught in other antitrust nets. 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.

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 to the breakup. In the vitamin B6 market, the Chinese share grew 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."[64]

As the vitamin B6 example illustrates, there are often multiple factors that contribute to cartel breakup. For each cartel in our sample, we have selected the factor that was most significant in the cartel's final breakup. There are six cartels in our sample that we code as breaking up primarily due to cheating; they lasted 7.7 years on average, but some are quite short-lived. The aluminum phosphide cartel, for instance, ended because one firm charged substantially lower prices than the target price set by the cartel.[65] 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.

IV. EMPIRICAL MODEL

A. Hazard Model

[64] European Commission Decision of 21 November 2001, Case COMP/E-1/37.512 – Vitamins, par. 348.
[65] Dauner (1994).

We estimate a proportional hazard model, specifying the probability of cartel breakdown as a function of variables that influence the stability of collusion. The hazard function λ(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 (that is, the cartel dissolves) at time t, given that it has not already occurred.

A proportional hazard model with a vector of covariates, **x**, can be written as

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

where κ(.)>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 κ(**x**) of observed covariates. Typically, κ(.) is parameterized as κ(**x**)=exp(**xβ**), where **β** is a vector of parameters and exp(x**β**) is a shift factor that depends on economic variables. 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 **β** 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 **β** 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. Similarly, 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 Duration

We now turn to a discussion of the variables included in our estimates of the parameter vector β. Summary statistics for all variables are included in Table 4. 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. The presumptive measure of the discount rate is the market interest rate. We use the average annual interest rate on three-month Treasury Bills (T-BILL), which represents the short-term market rate of interest generally 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).[66] The leverage ratio and interest coverage, standard measures of firm indebtedness, are defined as follows:

Leverage ratio:

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

[66] 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.[67] 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 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 vulnerable firm in the cartel, and hence the firm with the greatest incentive to cheat.

The second set of variables is intended to capture several ways in which cyclical fluctuations may affect cartel duration. We distinguish between business cycle fluctuations which are essentially common knowledge and those that are potentially unobserved or unexpected shocks to demand. In order to capture the latter, we measure demand fluctuations by estimating a non-linear trend in global GDP using the Hodrick-Prescott filter.[68] 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. Managers remember more than one period, and they can imagine economic shocks that are not linear. The HP filter reflects 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.[69]

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[67] 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.

[68] 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 (1997) varies with the frequency of the data. We have annual GDP data, and thus we set $\lambda = 6.25$ (Ravn and Uhlig, 2002).

[69] Dick (1996) models demand shocks with a first-order autoregressive process, AR(1). 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 a more sophisticated understanding of macroeconomic phenomenon on the part of cartel participants.

In some estimates, 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. Shocks are measured as the difference between actual and trend GDP (as determined by the HP 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. Neither positive nor negative deviations from trend appear to have any systematic affect on cartel stability. We also consider the possibility that publicly observed business cycle fluctuations affect cartel stability. We test for this "Rotemberg-Saloner" effect by including fluctuations in global GDP. In none of these specifications did changes in GDP affect the probability of break up (or change the significance of other coefficients).[70]

Because these are international cartels, fluctuations in exchange rates are also potentially disruptive to collusion.[71] Fluctuations in exchange rates redistribute profits because they can affect both prices and production costs. Exchange rate fluctuations affect cartel members in different countries asymmetrically so that previously agreed upon 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 (XER_SHOCK).

In order to capture the effect of the number of member firms on cartel stability, we create a dummy variable indicating whether a cartel had more than five members (MEM_OVER5). The participation constraint suggests that, within in a single industry, cooperation can be sustained as long as the number of firms is below some critical threshold. Our non-linear variable is consistent with Selten's (1973) classic article on 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).

[70] Domowitz et al (1987) and Borenstein and Shepard (1996) do find empirical support for the Rotemberg and Saloner prediction in their examination of prices and price-cost margins in industries in which there may be *tacit* collusion.

[71] Alexander (2003) provides the only previous empirical test of the impact of exchange rates on cartel stability. de Roos (2006) includes exchange rates in his analysis of price wars in the lysine industry, but as an instrument that shifts consumer demand, not for its impact on cartel behavior.

As discussed above, *customer* concentration may also be an important determinant of cartel stability. 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.[72] 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.[73] This measure varies from our ideal measure in two ways. First, we must choose one primary downstream industry. Since the primary 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. That this is a real challenge, for at least some cartels, is clear in the documentary record. DRAM customers describe the actions taken by Dell in response to suspicion that a cartel was responsible for the increase in prices it had observed.

> In 2002, Dell began to suspect that there was "cartel-like" behavior in the industry. On April 30, 2002, Dell's founder and Chief Executive Officer, Michael Dell, spoke at the Merrill Lynch "Hardware Heaven" conference. During Michael Dell's presentation, he said, "I think we saw cartel-like behavior by a couple of DRAM suppliers." As a result, Dell announced that it would widen its network of suppliers to try to defeat the anti-

[72] Dick (1996), p. 261.
[73] Further details on how this variable was constructed are given in the Appendix.

competitive conspiracy (par 195 amended complaint California Case M:02-cv-01486-PJH Document 1827 Filed 02/27/2008, page 41).

V. REGRESSION ANALYSIS

In order to capture the effects of antitrust policy on cartel breakup, we estimate a competing hazard model in which we jointly estimate the effects of these various measures on the probability of different causes of cartel "death."[74] In order to maintain sample size, we group cartel deaths into two over-arching categories: deaths that result from a violation of the participation constraint, including a member's decision to defect to the antitrust agency, and deaths that result from intervention by antitrust agencies without voluntary action on the part of a cartel member.[75]

Turning first to the determinants of cartel breakup by antitrust authorities – that is, the determinants of getting caught – we find that cartels that used market allocation mechanisms were significantly less likely to be broken up by the authorities than those that did not (Table 6, note that this is the implication of a point estimate less than one). Stigler (1964) long ago recognized the appeal of coordinating via market share rules: "Fixing market shares is probably the most efficient of all methods of combating secret price reductions" (p. 46), and the 80% of the cartels in the sample that chose to use market allocation mechanism clearly agree. But market allocation rules appear to stabilize cartels largely by making them invisible to the authorities. We find no significant effect of market allocation mechanisms on "natural death" (results not reported here). Similarly, cartels that actively punish members who cheat were significantly less likely to be caught by the authorities. We suspect that these punishments create the appearance of competition, and presumably fewer complaints from customers, so that competition authorities are less likely to devote resources to investigating the industry. On the other hand, the active involvement of trade associations seems to tip the authorities off – and to provide an evidence trail – that increases the likelihood that a cartel will be broken up by them. We test whether highly concentrated industries are more likely to be broken up by the authorities, as one might expect that such industries would draw the attention of authorities. However, we find that concentration has no systematic impact on the likelihood of "death by

[74] For general discussion of competing risks models, see Katz and Meyer (1990) and Hill et al. (1993).
[75] Note that this means that we include breakups associated with an amnesty (but not amnesty plus) application in the first category for the reasons outlined in section II.D.

antitrust." This may reflect the high level of concentration in these industries: average C4 is almost 75% (Table 5). Distinguishing among such highly concentrated industries may seem pointless to the authorities. Because customer complaints are behind at least some anti-cartel investigations, we also consider the possibility that a concentrated customer base – presumably reflecting larger customers who are more likely to be savvy enough to detect the existence of collusive pricing – might increase the probability of breakup by antitrust authorities. However the results here suggest that there is no effect of downstream customer on antitrust breakup. As we discuss below, while large customers may be quite happy to collect damages after cartel breakup – as evidenced by the large number of civil suits in the United States, and increasingly elsewhere – they tend not to be proactive in undermining upstream cartels. Finally, and not surprisingly, we find a large, significant increase in the probability of breakup by antitrust enforcement in the post-1995 period, associated with the changes in cartel policy that followed the U. S. Justice Department's investigation into the lysine cartel precipitated by Mark Whitacre's whistle blowing.

We turn now to a discussion of the results of our estimates of the determinants of the probability of "natural death." As with "death by antitrust" we see a significant Whitacre effect on the probability that cartels will collapse on their own (Table 7, model 4), This effect is smaller than is the case for death by antitrust, as might be expected, but reflects the very real change in incentives that changes in antitrust policy have wrought. We also test for the impact of increasing number of cartel members, which theory suggests may undermine cartel stability. As has been the case in every cross-sectional study of cartel duration in every era, we find no impact on the probability of cartel breakup (Table 7, model 4). We present the results here using the total number of cartel members. In estimates not reported here we tested for tipping points in the number of cartel members. No measure had any impact on expected cartel duration.[76]

Our measure of industry concentration is MINC4, the minimum four-firm concentration ratio of the industry in which the cartel was active (see Table 4 for descriptive statistics). The concentration ratios are drawn from both industry and government sources, but are generally not systematically reported by any statistical agency or trade publication. 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, because that is all we were able to obtain. For example, the bromine industry consisted of three major producers with a global three-firm concentration ratio of 83 percent in 1998.[77] The C4 would certainly have been higher, but without an estimate of the market share of the fourth largest firm, our best estimate of the *minimum* C4 is 83 percent. We do not have consistent measures of market share over time. The bromine cartel lasted from 1995 to 1998, but the market share information that we have is from 1998.[78] We are implicitly assuming that MINC4 is relatively stable over the life of the cartel; generally, concentration ratios do not in fact vary dramatically from year to year. When we test for the impact of industry concentration on cartel stability, we find no effect at all (Table 7, model 5).

We turn now to potential effects of downstream industry structure. The point estimate of the coefficient on CUSTCONC is 0.41, which is consistent with Stigler's notion that large customers contribute to cartel instability. But the estimate is not statistically significant. While this may reflect a small decrease in sample size when we introduce this variable – because we are unable to obtain measures of downstream concentration for all industries, this result is consistent with our general observation that large customers do not increase the incentive of firms to cheat on the cartel.[79] Rather, these large customers simply receive discounts—agreed upon by cartel members—from the cartel price. In the electrical and mechanical carbon products cartel, for example, large customers had bargaining power and did not always accept the announced cartel price.[80] In the sorbates cartel, producers explicitly set a separate target price for the largest or "ultrabig" purchasers.[81] In the bitumen cartel, producers and the five largest customers explicitly colluded to limit rebates to smaller customers. These large customers were fined along with the cartel producers by the European Commission. The Commission wrote in its report that

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[76] See Levenstein and Suslow (2006a, pp. 57-61) for a survey of previous findings on the relationship between industry concentration, the number of cartel members, and cartel duration.
[77] Chang (1999, p. 3).
[78] Warren (1999).
[79] See Levenstein and Suslow (2006a), pp. 61-64, for a review of the empirical literature on the relationship between customer size and cartel stability.
[80] European Commission Decision of 3 December 2003, Case C.38.359 – Electrical and Mechanical Carbon and Graphite Products, par. 76 and 106, as examples.
[81] See "United States of America v. Yuji Komatsu, Yoshihiko Katsuyama, Wakao Shinoda, and Hitoshi Hayashi," Indictment, Jan. 23, 2001, http://www.usdoj.gov/atr/cases/f7300/7366.htm. The rubber chemicals cartel also regularly gave discounts to its largest customers. The European Commission reports, for example, that Flexsys assured Bayer of its "support for Crompton/Uniroyal's price increase initiative, other than at Goodyear" (European Commission Decision of 21 December 2005, Case COMP/F/38.443 – Rubber Chemicals, par. 149).

> the purpose of most meetings simply was to agree on a single new bitumen price and two rebates, one for the W5 [the large consumers] and one for the smaller road builders (EC Decision, par 60). … For a period lasting at least between 1 April 1994 and 15 April 2002, collusion existed between and within a group of bitumen suppliers, consisting of Kuwait Petroleum, Shell, Klöckner, Wintershall, BP, Esha, Total and Nynäs, and a group of large Dutch road builders, consisting of KWS, Heijmans, BAM NBM, HBG, Ballast Nedam and Dura Vermeer, to regularly fix for sales and purchases of road pavement bitumen in the Netherlands as to the following: (1) the gross price; (2) a uniform (minimum) rebate on the gross price for that group of road builders; (3) a smaller (maximum) rebate on the gross price for other road builders. (par 48)

We now consider the impact of various organizational characteristics of cartels on the probability of "natural" death. Surprisingly, market allocation – which was so important in preventing antitrust breakup – had no significant impact on natural death. Similarly, monitoring had no significant impact on natural death (results not reported here). In both cases, these practices are pervasive. Approximately 80% of all cartels engage in each of these behaviors (Table 4). So there may simply not be enough variation to make a measurable difference in our estimates. Other organizational characteristics did have a significant impact on cartel stability. The active use of a trade organization – which significantly increased the probability of being caught –significantly decreased the probability of breaking up on one's own (Table 4). Cartels appear to face a tradeoff: the involvement of a trade association helps to stabilize the cartel, providing a mechanism for communication and mediation. But it also increases the cartel's visibility and the written record of its conspiratorial activities, making it more vulnerable to prosecution. From a policy maker's perspective, this also suggests that targeting the activities of industry associations has a greater benefit, because it removes from cartel's arsenal a technique that is particularly helpful for internal stabilization.

In these estimates we distinguish two types of responses that cartels may take to outcomes that are at variance with the collusive agreement, such as a member selling above its allotted quota. In some cartels, it is understood that variations in demand (or the need to maintain cartel secrecy, and therefore to provide customers with quotations when asked) may result in some firms having greater or lesser sales than is contemplated in the cartel agreement. These cartels plan for such variations, usually by requiring that firms that oversell their quota purchase the amount of excess output from another cartel member. Cartels that have such a compensation scheme are significantly less likely to die a natural death (Table 7, model 4). This undoubtedly reflects the ability of these compensation schemes to align the incentives of cartel members. It

also probably reflects the level of organizational trust and cohesion necessary to implement such a scheme. We distinguish these compensation schemes from the implementation of retaliatory punishments in response to perceived cheating. As we saw above, these punishments decrease the likelihood of death by antitrust. But they significantly *increase* the likelihood of natural death (Table 7, model 4). Cartels that have to punish are not stable cartels.

The one other organizational characteristic that appears to have a marginally significant impact on cartel stability is exclusion. Since cartels only take such actions when there is a credible threat of entry, one might imagine that this measure could have an ambiguous "effect" on cartel stability. These actions increase cartel stability, but their implementation suggests a threat to that stability exists. Overall cartels appear to be able to find and implement successful exclusion, as those that undertook actions to exclude entrants or expansion by peripheral firms were in fact somewhat less likely to break up (Table 7, model 4).

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 consider the cartel-specific discount rates discussed above that are designed to reflect the financial stability of the weakest member of the cartel. We also consider market interest rates, on the assumption that, with relatively perfect capital markets, these interest rates reflect the opportunity cost of waiting for most market participants. Financial distress can severely shorten a firm's time horizon, increasing the risk of cartel breakup. In Table 7, model 7, we report the results using the 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 this variable is significant and much greater than one, indicating that the presence of a cartel member with income insufficient to cover interest payments increases the probability of cartel breakup by 52 percent. Consistent with Busse's (2002) results, this suggests that firm-specific measures are the relevant measure of the discount rate for cartel stability. Firm-specific rates capture the impatience of those firms that constitute a binding constraint on cartel stability.

In contrast, when we add T-Bill to the model specification, we find that fluctuations in the rate of interest have no significant impact on the probability of cartel breakup (Table 7, model 8). It may be that this measure 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.

Following the suggestion posited in the Green and Porter model, we consider the effect of "unexpected" demand shocks. Previous cross-sectional studies have found that macroeconomic volatility in demand reduces cartel life spans (Suslow 2005, Dick 1996).[82] We find that deviations from trend GDP (HP_GAP) show a consistent, statistically significant impact on the probability of breakup (Table 8, model 8).[83] In results not reported here, we separately test the impact of negative and positive shocks. Positive shocks have no impact on the probability of breakup, while negative shocks have an effect similar to what is reported here.

We also consider the possibility that publicly observed business cycle fluctuations affect cartel stability. We test for this "Rotemberg-Saloner" effect by including fluctuations in global GDP (Table 8, model 9). We also consider other specifications, including changes in the global growth rate and fluctuations in national GDP. In none of these specifications did changes in GDP have any significant effect the probability of break up.[84] This is consistent with most case studies of individual cartels. Such studies rarely report any role for macroeconomic fluctuations in cartel stability (Levenstein and Suslow 2006a). Thus, unexpected deviations, especially negative deviations, from trend appear to destabilize these cartels. Positive shocks and predictable business cycle variation do not.

Despite our speculation that exchange rate fluctuations would be a destabilizing force for international cartels, we consistently found *no* effect on cartel stability. This may reflect the difficulty in capturing the shocks to individual cartels using aggregate data (in this case, a trade-

[82] 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.

[83] We also tried a specification of demand "shocks" including squared deviations from the HP trend to capture the idea that particularly large deviations, in either a positive or negative direction, may disrupt collusion. This measure had no significant effect on the probability of cartel breakup.

[84] Domowitz et al (1987) and Borenstein and Shepard (1996) do find empirical support for the Rotemberg and Saloner prediction in their examination of prices and price-cost margins in industries in which there may be *tacit* collusion.

weighted index of the value of the U.S. dollar).[85] Alternatively, it may be that international cartels are aware of exchange rate fluctuations and develop strategies for coping with them.[86] For example, the specialty graphite cartel had provisions in its agreement that allowed for currency fluctuations, and, on one occasion decided on an "emergency increase [in particular countries] of 5-10%" due to exchange rate fluctuations.[87]

Our results are consistent with Suslow's (2005) study of international cartels in the first half of the twentieth century. For those cartels, organizational measures were shown to increase duration, although the Great Depression and World War II dominated all other effects. In particular, she found that patent pools and cross licensing had a consistently significant effect on cartel contract duration. Today, licensing contracts are generally not made public, so we simply do not know whether intellectual property agreements continue to play a role in facilitating collusion. Our results are also broadly comparable to Griffin (1989), who finds that cartel organization increased cartel "performance," as measured by the Lerner Index, for a sample of international commodity cartels active at some time between 1888 and 1982.[88]

VI. CONCLUSION

We find that the behavior of the old sugar cartel, as documented by Genesove and Mullin, is not an anomaly: twenty-first century cartels also develop sophisticated organizational mechanisms to cope with economic uncertainty and change. Those that develop effective shock absorbers last longer, all else equal. Some of our results are consistent with the conclusion of Green and Porter (1984). In particular, we find that negative deviations from trend growth in demand have a negative impact on cartel stability. On the other hand, our results suggest that the theoretical focus on price wars and cheating may be misdirected. Cheating is rarely the cause of

[85] 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.

[86] Ideally, we would have included strategies for coping with exchange rate fluctuations in our organizational index, but the evidence that we have of this is spotty and anecdotal.

[87] European Commission Decision of 17 December 2002, Case COMP/E-2/37.667 – Specialty Graphite, par. 205. As the Decision describes, numerous facets of this cartel agreement were designed to "harmonize" trading conditions, including an agreement to set up "standard" exchange rates (par. 100).

cartel breakup. Instead, successful cartels develop organizational mechanisms to monitor compliance and provide disincentives to cheating, including compensation schemes. Cartels that do punish cheating are more likely to break up, suggesting that the notion of "equilibrium price wars" may be misleading. We find no support for the Rotemberg and Saloner (1986) hypothesis that cartels are more likely to "break down during booms." We find no impact of overall business cycle fluctuations on cartel stability. Short term market interest rates have no effect on cartel stability, but firm specific measures of impatience, such as the ability to handle one's debt load, are systematically related to cartel breakup. Firms that are in dire straights do not make good cartel partners.

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. The impact of the change in policy is also reflected in the significant increase in the likelihood of cartel breakup after 1995, for both those firms broken up by anti-trust authorities and those that died a "natural death." Trade associations appear to be a tell tale sign for competition authorities, as cartels that rely on them are more likely to be caught and broken up. On the other hand, cartels that use market allocation mechanisms and those that actively punish defections are more likely to be able to escape detection, at least until after they have fallen apart on their own.

Despite the valiant attempts of industrial organization economists since Bain (1959) to establish an empirical relationship between concentration and cartel stability, like those preceding us, we are unable to demonstrate such a connection. Industry concentration may influence where cartels are attempted, but differences in concentration do not appear to affect duration. Whether the four-firm concentration ratio is, for example, sixty percent or ninety percent is not as important as whether all the major producers are included in the cartel. When large producers remain outside the agreement, cartels fall apart.

Cartels can also function with large numbers of members, especially if they make use of trade associations, which significantly *decrease* the likelihood that a cartel will die a "natural

[88] Griffin (1989, p. 193). He measures organization with "a subjective index, which on a scale of 1 to 10 ranks cartel organizations according to the direct and indirect policing powers of the cartel" (p. 187).

death." This is consistent with Sutton's (1997) argument that there is a fundamental indeterminacy in the equilibrium number of firms where collusion is possible. As Sutton remarks, in a broader comment on game-theoretic models, "[s]hould we see this as a success, or as an embarrassment?"[89] Given the weight of empirical findings from numerous studies of historical cartels, as well as our findings from contemporary international cartels, we believe that we should see this neither as a success, nor an embarrassment, but as an empirically established fact.

[89] Sutton (1997), p. 66.

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 (trade weighted) 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—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 are available for each firm with a GVKEY for the full sample period 1971-2002,

but Compustat Global only contains data from 1993 – 2005.[90] 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).[91] 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.[92] 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.[93]

[90] 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.
[91] 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.
[92] These cartels are beer (Luxembourg), marine transportation services, plastic dinnerware, stamp auctions, tampico fiber, and zinc phosphate.
[93] 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

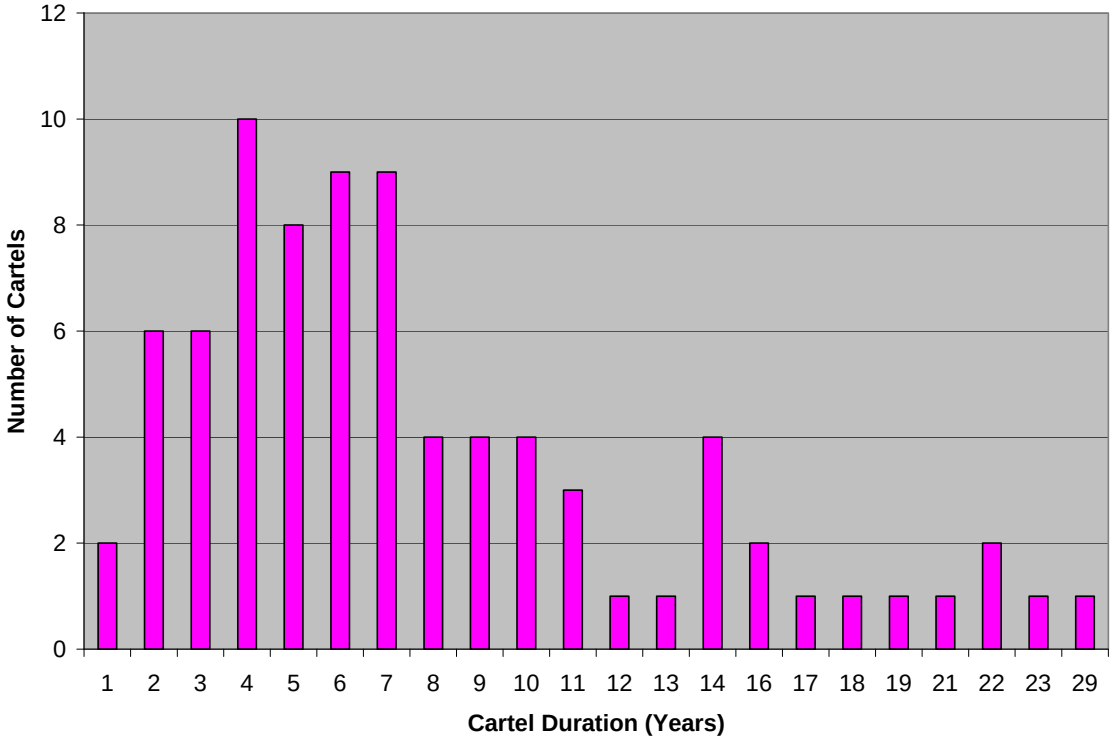

FIGURE 2

PROBABILITY OF SURVIVAL

FULL SAMPLE

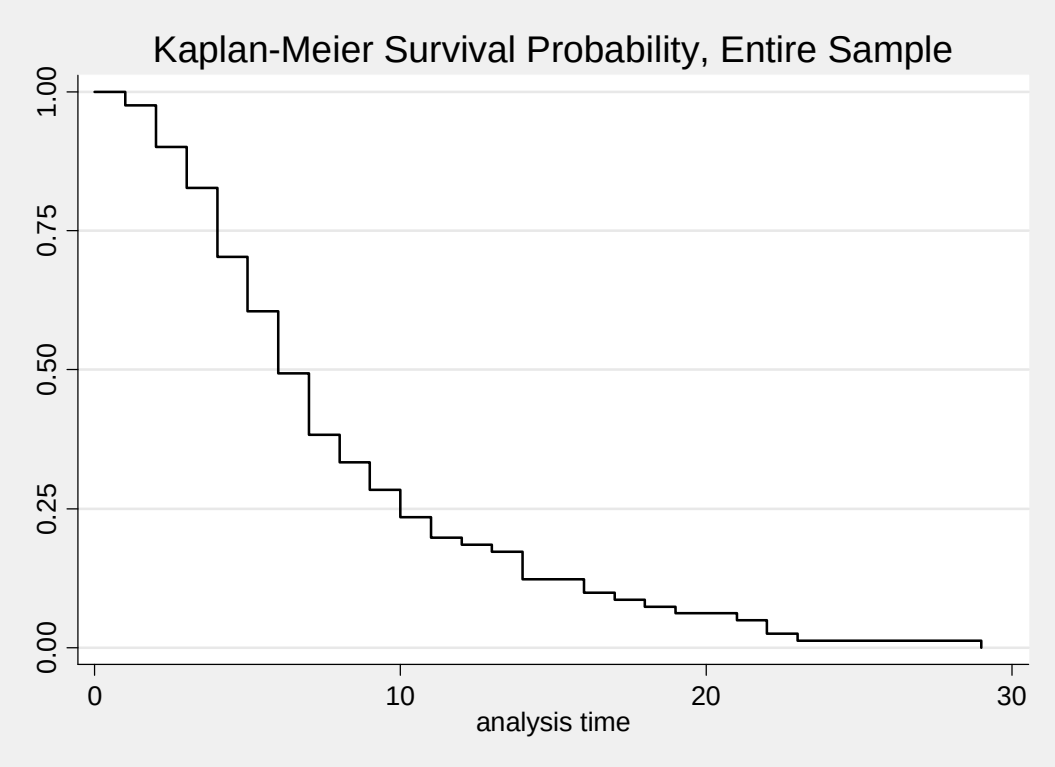

FIGURE 3

PROBABILITY OF SURVIVAL

COMPARISON OF CARTELS BY NUMBER OF MEMBERS

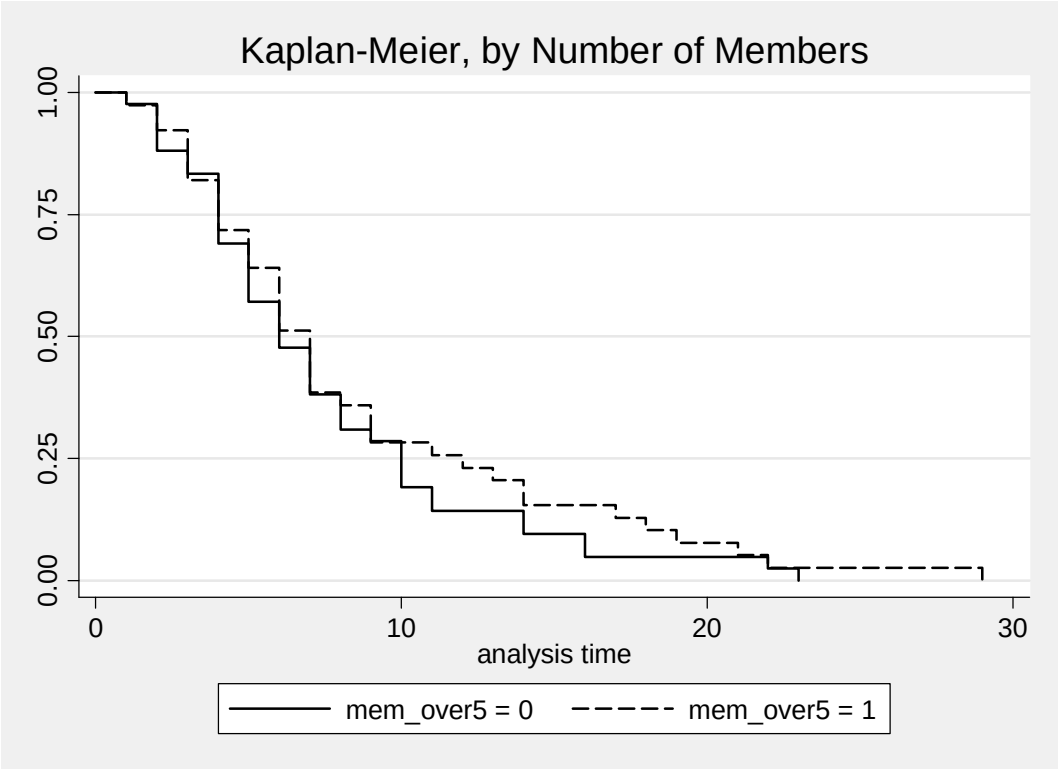

FIGURE 4

PROBABILITY OF SURVIVAL

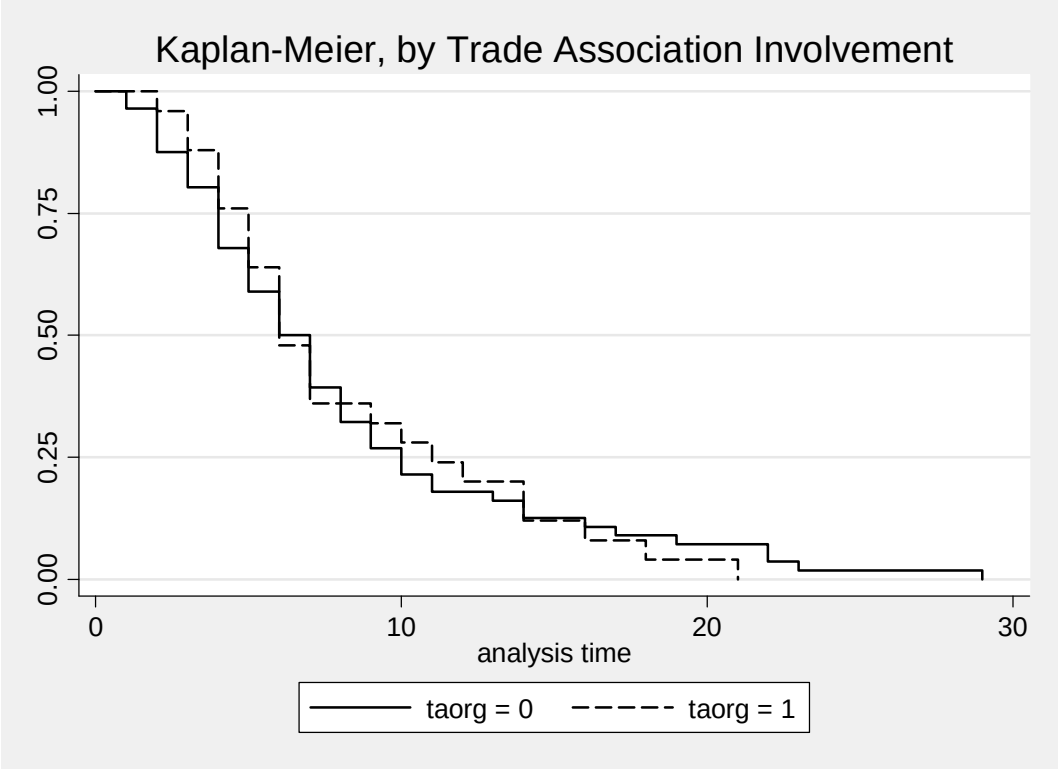

FIGURE 5

PROBABILITY OF SURVIVAL

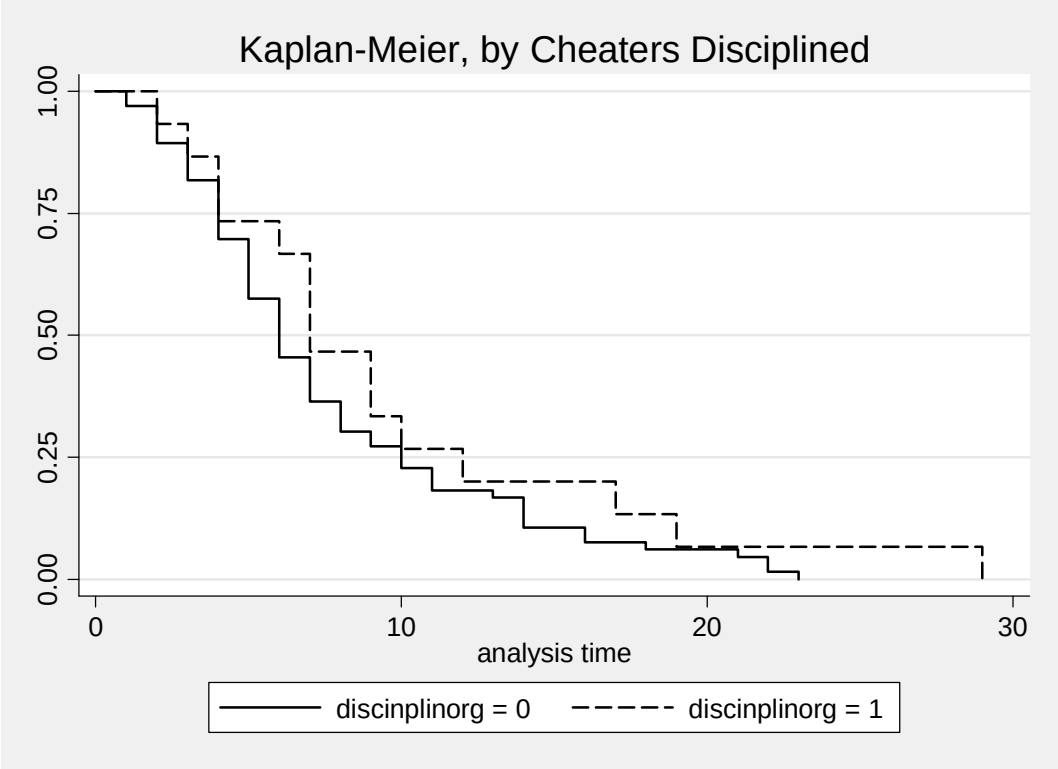

FIGURE 6

PROBABILITY OF SURVIVAL

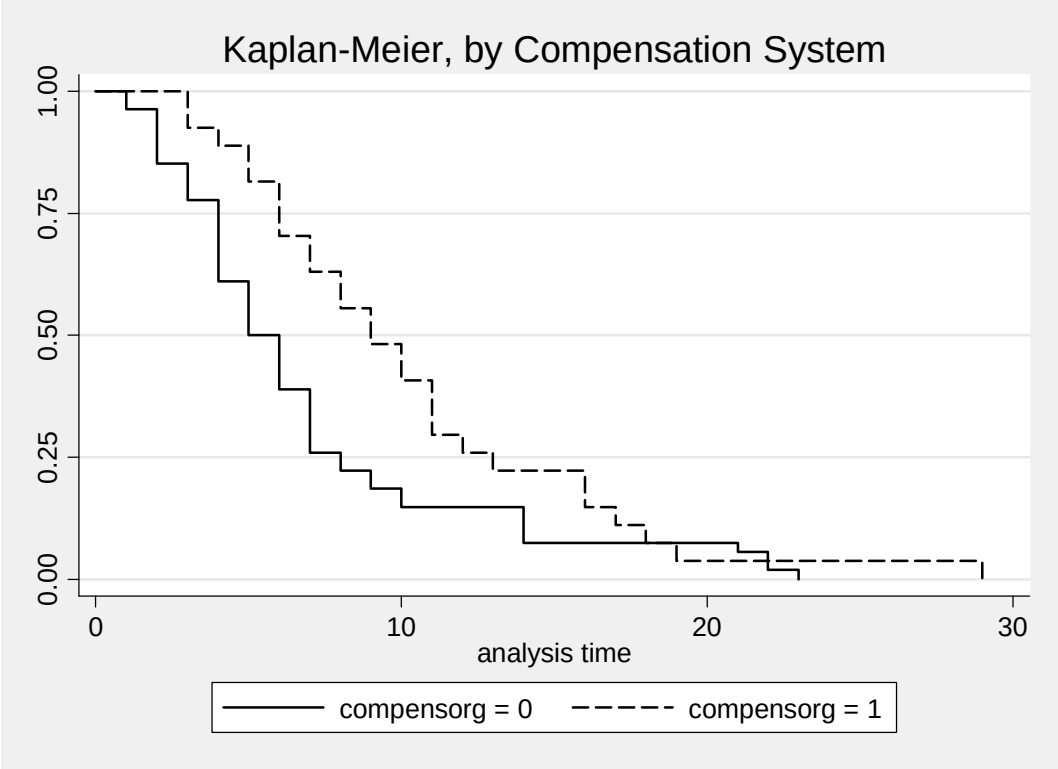

FIGURE 7

PROBABILITY OF SURVIVAL

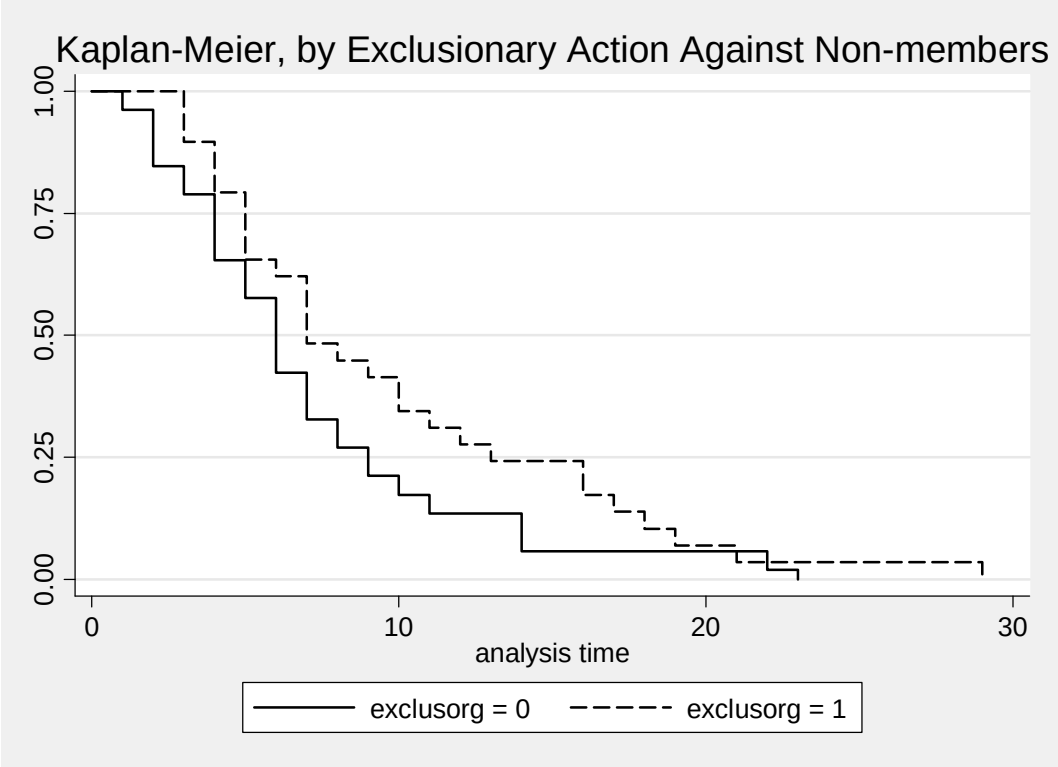

FIGURE 8

PROBABILITY OF SURVIVAL

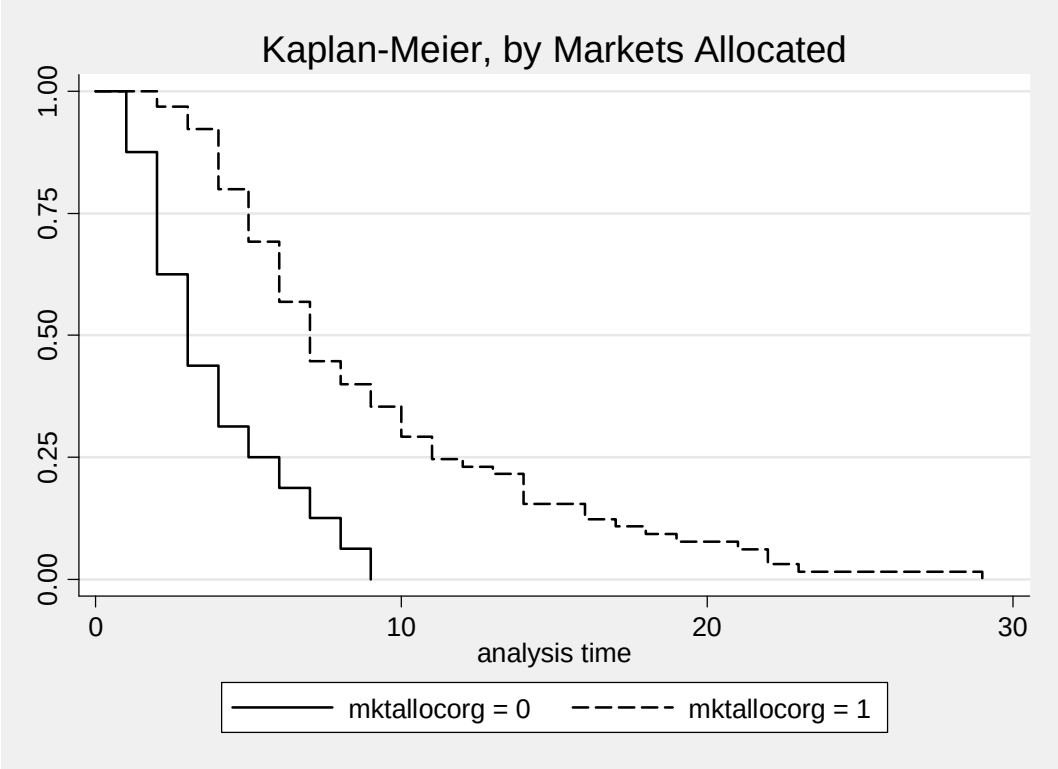

FIGURE 9

PROBABILITY OF SURVIVAL

TYPES OF DEATH

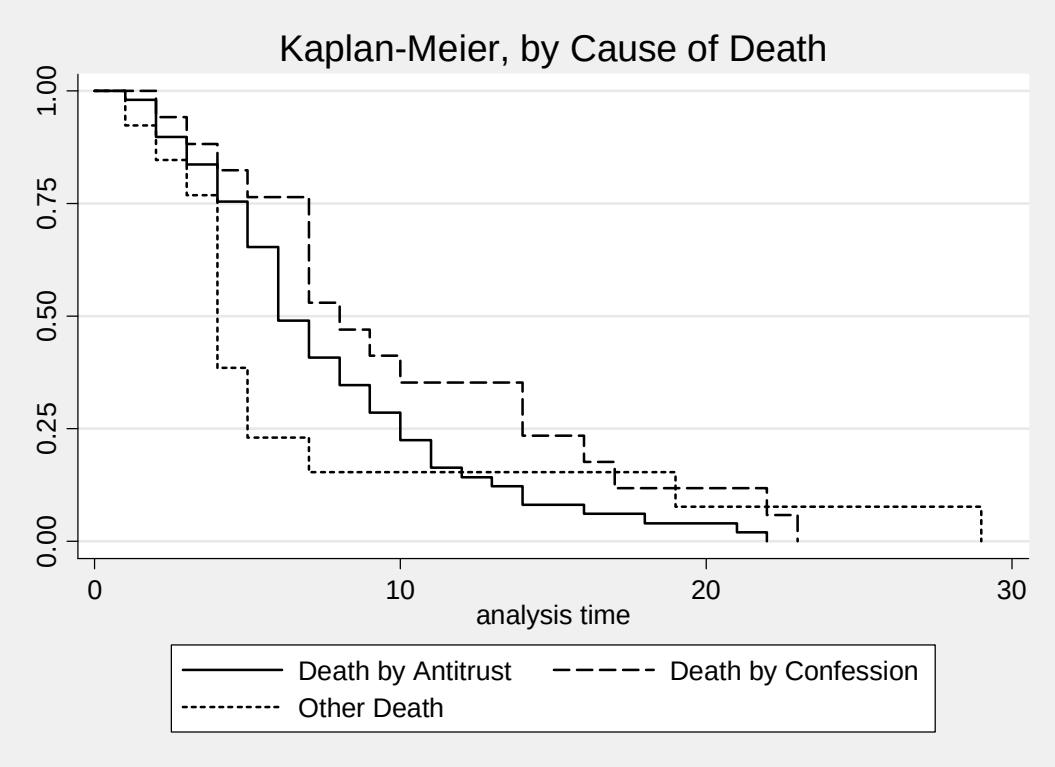

TABLE 1

SECTORAL COMPOSITION OF CONTEMPORARY INTERNATIONAL CARTELS

Sector	**Percent**
Chemicals	39.51
Metal and Minerals	16.05
Non-manufacturing	19.75
Other Manufacturing	24.69

TABLE 2

CARTEL DURATION: COMPARISON TO PREVIOUS STUDIES

	Contemporary International Cartels	*Other International Studies*			*U.S. Studies*	
Duration		*Eckbo*[a]	*Griffin*[b]	*Suslow*[c]	*Posner*[d]	*Gallo et al.*[e]
Mean (years)	8.1	5.3	7.3	8.3	7.5	5.4
Standard deviation	5.8		6.3	6.2		
Range	1 – 29	1 –18	1 – 29	1 – 13		
% <5 years	30%			40%		
% > 10 years	23%			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

	Current Sample	*Hay & Kelley* [b]	*Fraas & Greer*	*Posner*	*Gallo et al.*
Market Allocation[a]	80%	35%	26%	26%	27%
Bid Rigging	23%	29%	19%	14%	30%
Distributor Involvement	15%				
Terms & Conditions of Sales Set	44%	14%	5%	14%	
Product Standardization	7%				
Monitoring	80%				
Hierarchy	43%				
Trade Association	31%	29%	36%	44%	23%
Compensation Rules	33%			4%	
Disciplinary Practices	19%				
Exclusion	35%				
Either discipline or exclusion	43%	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 = 81 unless otherwise stated

Variable Name	Definition	Min	Max	Mean	Standard Deviation
ORGANIZATIONAL VARIABLES					
BIDRIGORG	1 if bids were rigged	0	1	0.24	0.43
MKTALLOCORG	1 if shares, regions, or customers were explicitly assigned to cartel members	0	1	0.80	0.40
STDIZEORG	1 if cartel standardized product characteristics	0	1	0.08	0.27
OTHERTERMSORG	1 if cartel set terms other than price (for example, limiting discounts or terms of sale)	0	1	0.45	0.50
DISTNORG	1 if cartel included distributors or vertically integrated producer/distributor firms	0	1	0.15	0.36
TAORG	1 if trade association involved	0	1	0.31	0.47
MONITORORG	1 if sales information exchanged for monitoring purposes	0	1	0.79	0.41
DISCIPLINORG	1 if retaliatory action taken following cheating	0	1	0.19	0.39
COMPENSORG	1 if members agreed to a compensation scheme	0	1	0.33	0.47
EXCLUSORG	1 if cartel took exclusionary action against non-members	0	1	0.36	0.48
HIERARCHORG	1 if multiple levels of organizational hierarchy existed within cartel	0	1	0.43	0.50

OTHER VARIABLES

Variable Name	Definition	Min	Max	Mean	Standard Deviation
T-BILL (37 annual observations)	Annual average rate on U.S. Treasury bills, 3-month maturity	1.01	14.04	5.31	2.04
INTCOVERAGE (73 cartels)	Interest coverage ratio for cartel member firms	-28.76	69.75	4.42	4.51
INTCOVERAGE<1 (73 cartels)	1 if INTCOVERAGE is less than 1	0.00	1.00	0.04	0.21
LEVRATIO (73 cartels)	Financial leverage ratio for cartel member firms	0.19	1.65	0.76	0.16
CHANGE IN WORLD GDP GROWTH RATE (37 annual observations)	Change in world GDP growth rate	-5.02	3.82	-0.02	1.10
WORLDGDPRATE (37 annual observations)	% Change in world GDP	0.43	6.18	2.89	0.95
HP_WORLD_GAP (37 annual observations)	Level of gap between world GDP and trend (using HP filter) ($ billions)	-319.41	407.31	-0.82	155.93
POS_HP (37 annual observations)	Level of gap between GDP and trend (using HP filter) if gap is positive ($ billions)	0.00	407.31	59.15	104.45
NEG_HP (37 annual observations)	Level of gap between GDP and trend (using HP filter) if gap is negative ($ billions)	-319.41	0.00	-59.97	79.38
XER_SHOCK (37 annual observations)	Absolute value of the difference between current and lagged exchange rate index value	0.13	9.71	3.24	2.56
MEM_OVER5	1 if cartel has more than five members	0.00	1.00	0.52	0.50
MINC4 (57 cartels)	Minimum four-firm concentration ratio	24.00	100.00	74.78	18.40
CUST_C4_I (57 cartels)	C4 ratio for the industry that is the cartel's most important customer	1.00	90.00	34.41	23.36
CART_C4_i (78 cartels)	C4 ratio for the cartel's industry	6.18	90.60	47.74	20.14
CUSTCONCHIGH (76 cartels)	1 if cartel's customers are concentrated	0.00	1.00	0.06	0.24
CONCHIGH (63 cartels)	1 if cartel is concentrated	0.00	1.00	0.72	0.45
CHEM	1 if cartel in chemicals sector	0.00	1.00	0.41	0.49

TABLE 5

CAUSES OF CARTEL BREAKUP

Cause of Breakup	Number of cartels	Average Duration (years)
Government-Initiated Breakup Triggered By:		
Amnesty application	17	10.29
Follow-on investigation	13	8.77
Customer complaint	7	4.00
Other sources (including whistleblowers)	29	8.17
Other Breakup		
Cheating	6	7.67
Growing fringe	7	6.43
Unknown Cause of Breakup	2	4.50
Total	*81*	*8.07*

TABLE 6

PROPORTIONAL HAZARDS MODEL

DETERMINANTS OF CARTEL DEATH

DEATH CAUSED BY EXOGENOUS ANTITRUST INTERVENTION

Variable	Model 1	Model 2	Model 2
	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)
WHITACRE	4.36**	6.59**	7.56**
	(3.77)	(2.71)	(2.76)
NUMBER MEMBERS	1.03	1.08	1.08
	(1.07)	(1.54)	(1.59)
MARKET ALLOCATION	0.23**	0.20**	0.12**
	(-3.72)	(-2.67)	(-3.43)
TRADE ASSOCIATION	2.52**	2.16**	2.05*
	(2.64)	(1.96)	(1.78)
PUNISHMENTS IMPLEMENTED	0.39**	0.41	0.58
	(-2.06)	(-1.59)	(-1.00)
PRODUCER C4 CONCENTRATION		1.02	1.01
		(1.36)	(0.96)
HIGH CUSTOMER CONCENTRATION			1.17
			(0.25)
Number of Cartel Failures	49	33	33
Number of Obs.	654	446	437
Log likelihood	-154.2	-90.3	-88.0
Likelihood ratio χ^2	39.9 (df=5)	29.0 (df=6)	32.37 df=7

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

TABLE 7

PROPORTIONAL HAZARDS MODEL

DETERMINANTS OF CARTEL DEATH: DEATH CAUSED BY "NATURAL DEATH"

Variable	Model 4	Model 5	Model 6	Model 7	Model 8
	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)	Hazard Ratio (z-statistic)
WHITACRE	4.43**	2.06	4.07**	2.86**	2.82**
	(3.29)	(1.4)	(3.02)	(2.13)	(2.1)
NUMBER MEMBERS	0.95	0.98	0.95	0.93	0.93
	(-0.88)	(-0.22)	(-0.87)	(-1.09)	(-1.11)
TRADE ASSOCIATION	0.21**	0.20**	0.23**	0.23**	0.23**
	(-2.42)	(-1.97)	(-2.27)	(-2.15)	(-2.15)
PUNISHMENTS	3.94**	2.47	3.21*	3.50*	3.43*
IMPLEMENTED	(2.23)	(1.25)	(1.65)	(1.78)	(1.74)
COMPENSATION PLAN	0.16**	0.15**	0.17**	0.17**	0.17**
USED	(-2.61)	(-2.42)	(-2.32)	(-2.38)	(-2.38)
EXCLUSIVE TACTICS	2.14	1.81	2.08	2.31*	2.35*
EMPLOYED	(1.53)	(1.04)	(1.47)	(1.64)	(1.66)
PRODUCER C4		1.00			
CONCENTRATION		(0.22)			
HIGH CUSTOMER			0.41		
CONCENTRATION			(-0.86)		
INTEREST COVERAGE				3.41**	3.30**
DUMMY				(2.26)	(2.14)
T-BILL					0.96
					(-0.25)
Number of Cartel Failures	32	24	28	29	29

Number of Obs.	654	446	610	499	499
Log likelihood	-93.5	-67.6	-80.7	-76.9	-76.9
Likelihood ratio χ^2	31.2 (df=6)	15.97 (df=7)	26.46 (df=7)	25.21 (df=7)	25.27 (df=8)

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

TABLE 8

PROPORTIONAL HAZARDS MODEL

MACROECONOMIC DETERMINANTS OF CARTEL DEATH: DEATH CAUSED BY "NATURAL DEATH"

Variable	Model 9 Hazard Ratio (z-statistic)	Model 9 Hazard Ratio (z-statistic)
WHITACRE	2.68**	2.24
	(1.95)	(1.56)
NUMBER MEMBERS	0.93	0.91
	(-1.13)	(-1.35)
TRADE ASSOCIATION	0.24**	0.24**
	(-2.09)	(-2.09)
PUNISHMENTS IMPLEMENTED	3.42*	3.25*
	(1.75)	(1.63)
COMPENSATION PLAN USED	0.17**	0.15**
	(-2.38)	(-2.42)
EXCLUSIVE TACTICS EMPLOYED	2.41*	2.98**
	(1.69)	(1.97)
INTEREST COVERAGE DUMMY	3.38**	3.07**
	(2.16)	(2.0)
T-BILL	0.93	0.76
	(-0.43)	(-1.36)
GLOBAL GDP GROWTH RATE	1.14	
	(0.45)	
HODRICK-PRESCOTT GAP		1.00**
		(1.94)
Number of Cartel Failures	29	29
Number of Obs.	499	499
Log likelihood	-76.8	-75.7
Likelihood ratio χ^2	25.47 (df=9)	28.96 (df=9)

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