

Polycentric Governance in Collusive Agreements^{*}

W. Benedikt Schmal[†]

Walter Eucken Institute & DICE, HHU Düsseldorf

January 31, 2024

Abstract

Collusive agreements in the form of cartels among firms are complex structures. The involved firms need to agree on prices and sales quotas that are legally not enforceable. Market characteristics that foster cartels' failure or success are widely examined. However, the interplay between the involved firms in a collusive agreement, i.e., the governance dimension within a cartel, has received surprisingly low attention. Using a comprehensive dataset of 191 cartels from 2012 - 2018, this paper empirically reveals that polycentric structures within the cartel governance may contribute to longer duration and lower sanctions imposed by competition authorities, especially for large cartels. By that, the paper sheds new light on two aspects: The entangled governance structures of collusive undertakings as well as the relevance of polycentricity in the firm environment. The insights may be helpful for cartel authorities and new research combining institutional and industrial economics.

JEL Codes: A14, D02, D23, K42, L40, O17

Keywords: Collusion, illegal cartels, polycentricity, governance, institutions

^{*}I am grateful for valuable feedback from Paul Aligica, Ilya Kukaev, and Anja Shortland, as well as from participants at the 2nd Markets & Society Conference 2023 in Falls Church, VA. This work Financial support from the Institute for Humane Studies (grant No. IHS016790) is gratefully acknowledged. I developed this project during my Oskar Morgenstern Fellowship at the Mercatus Center at George Mason University, for which I thankfully acknowledge funding and hospitality. All errors and views are my own.

[†]Walter Eucken Institute, Goethestr. 10, 79100 Freiburg (Br.), Germany. Email: schmal@eucken.de

1 Introduction

Corporate governance is a crucial driver of firm performance, value, innovation, and dividends paid (Bhagat & Bolton, 2008; Wu, 2008; Acharya et al., 2011; Ammann et al., 2011). There exist influential indices and measures (see, e.g., Gompers et al., 2003; Bebchuk & Cohen, 2005; Brown & Caylor, 2006) that shall capture corporate governance. Even though it is well-established in the management and finance literature, it is much less the case in industrial economics, particularly when it comes to cartels and collusion. We know since Adam Smith that “People of the same trade seldom meet together, . . . but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.” (Smith, 1776/1904, book I, p. 130). Moreover, even in ‘modern’ economics, the foundations of business cartels have been laid already by Stigler (1964). Thus, cartels are everything but a new phenomenon.

What prevails, though, is the common simplification of companies to abstract entities labeled ‘firm A’ and ‘firm B’ that interact based on the maximization of an infinite stream of expected profits (Schmal, 2022a), even though complex governance structures within and between firms are predominant. When studying business cartels, it neglects how entangled communication and coordination between firms in a cartel may become. As collusion is illegal in most countries, the involved firms need to set up incentive-compatible payoff schemes that are robust without relying on legal enforcement. The governance schemes of a cartel most likely reflect this.

Corporate governance *within* a firm is already an established subject of study. The same holds for market characteristics that foster or harm the formation and duration of cartels in industrial economics. This paper aims at the layer between the two, namely the governance among firms within a cartel. It aims to study how polycentric governance of such collusive agreements may be able to explain the stability of cartels. It is an attempt to widen the perspective of how one might look at cartels, their emergence, and their collapse, which considers mainly the internal governance within a cartel between its members.

I provide evidence that – different from canonical predictions – more cartel members do not destabilize a cartel but tend to extend the duration and mitigate the financial sentence for the cartel. Furthermore, sanctions imposed on detected cartels do not increase linearly in the number of cartel participants. Lastly, involved third parties such as business associations monitoring and clearing centers do not increase the stability of collusive agreements.

I explain this with the presence of polycentricity within the organizational structure of cartels. Precisely, I investigate the interactions among firms within a cartel. By that, I look at an intermediate layer of governance that appears to be hitherto underrepresented in the literature:¹ Plenty of research exists on the market environment of colluding firms. On the other hand, there is a growing body of literature on the mechanisms within a single firm that may lead to collusion. The present paper introduces the concept of polycentricity to the mesolevel of firm interaction within a cartel. Using a comprehensive dataset provided by the OECD, it can show assorted correlational evidence that can be reasoned with the emergence of polycentric structures in this governance dimension, which is likely to be present, particularly among large cartels.

Dick (1996) and Hyytinen et al. (2019) have studied cartel contract design. However, in both cases, legal cartels are studied, which has implications for the organizational structure, as polycentricity is likely to be a downward driver of sanctions. Furthermore, both cases focus on the mechanics of the cartel, i.e., to which extent firms collude on prices or quantities and how they compensate each other. This, however, leaves open questions regarding the overall governance structure of the cartel, which goes one level deeper because, within a governance framework, firms agree on their optimal strategies to execute the collusion. Haucap and Heldman (2023) descriptively investigate characteristics of the inner workings of cartels in Germany. Furthermore, Haucap et al. (2023) experimentally demonstrate that gender can affect the willingness

¹One notable exemption are the conceptual considerations by Schwalbe (2013).

to collude. Thus, there already exists important work that looks at the inner workings of cartels, but a strong institutional analysis of the governance structure in a more general way (and following Aligica, 2015) has been missing up to now.

The concept of polycentricity in governance structures has lately been applied to various collectively organized structures aside from public administration. Aligica et al. (2019) use it to propose a ‘polycentric stakeholder analysis’ to understand corporate governance and social responsibility better. It also succeeds in extra-legal governance structures such as kidnapping (Shortland, 2018) or the often not fully law-abiding market for precious art (Shortland & Shortland, 2020).

Enriching the interdisciplinary field of antitrust with methods of the public choice literature has been proposed lately by Shughart (2022) and tackles the decreasing heterogeneity in research on collusion (Schmal, 2022b). However, he calls for evaluations of antitrust law and institutions. I aim at studying collective action issues *within* cartels. It follows the broader call of Brams (2006) to bring public choice closer to practice. While he related this primarily to elections and conflict resolution, firm behavior became an influential topic again, looking at the so-called ‘big tech’ companies. I am able to give good reasons why polycentricity within cartels may be an essential driver of stability.

This is especially important as markets with many participants as well as cartels with many members are often considered unstable in theory (see, e.g., Huck et al., 2004; Selten, 1973). Empirically, it is not that clear. Levenstein and Suslow (2006) report in their review article that evidence is mixed on whether cartels with more participants are more or less stable compared to those collusive agreements with a small number of members.

The remainder of this paper is structured as follows. Section 2 describes the concept of polycentricity and how one can apply it to business cartels. Section 3 maps drivers of cartel failure and success to polycentric governance. In Section 4, I provide exploratory empirical evidence for polycentricity in detected cartels. Section 5 concludes.

2 The concept of polycentricity applied to cartels

The origins of the concept of polycentricity can be traced back to botanical studies that applied the conceptual pair of mono- and polycentricity to distinguish the reproductive methods of plants into those with one (mono) and those with many reproductive cells (poly). In the 1960s, it was adapted to study administrative structures (Stephan et al., 2019). Ostrom et al. (1961) observed for US metropolitan areas many different governmental units that are not hierarchically organized but independent and partially overlapping. Based on that, they defined polycentric structures as having more than one officially independent decision-making center that may act independently or be interrelated with other decision centers.

Ostrom (2005, p. 283) subsumed the concept as such that *“Each unit exercises considerable independence to make and enforce rules within a circumscribed domain of authority for a specified geographical area. . . . some units are general-purpose governments while others may be highly specialized. . . . These are nested in several levels of general-purpose governments.”* Needless to say, this definition was suited to the understanding of governance structures in public administration and requires sufficient adjustment for use in industrial organization. Nevertheless, considering the case of different hierarchy levels joint with general and special purpose management roles, it is easily conceivable that at least this universal definition applies to business cartels.

In their review article, Aligica and Tarko (2012) suggest that polycentricity may encompass three building blocks: Multiple decision centers, as already mentioned, an institutional framework with overlapping rules, and some spontaneous order in terms of market entry and exit as well as information availability. McPhail and Tarko (2017) structure these blocks as ‘structure,’ ‘process,’ and ‘outcome’ of a polycentric governance system and add an evaluation loop as an iterative element. Subsequently, I will go through all three issues and discuss how cartels and collusive agreements of firms can be related to this concept. At that point, I define a sample cartel as a collusive agreement between two firms, A and B, that want to optimize joint profits by

adjusting prices and quantities sold. Furthermore, these firms have several managerial levels, such as a board, top management, and middle management, e.g., regional or product managers. For the sake of simplicity, I set aside more details on the market modalities and structure.

Multiplicity of decision centers: As Aligica and Tarko (2012) state, it requires the ‘active exercise of diverse opinions’ as well as ‘autonomous decision-making layers.’ Last, there must be either common or individual goals. Sticking to the sketched situation, it is the case that both firms communicate their needs and their opinion on how to behave given the joint maximization of profits. Furthermore, there exists plenty of evidence that agents involved in collusive agreements communicate (Haucap & Heldman, 2023). Moreover, Harrington and Skrzypacz (2011) have theoretically proven that communicating its own sales figures – and by that implicitly stating its own demands for a successful extraction of the CPR of excess profits – can be equilibrium behavior. Furthermore, sales and target profits are always, at least to some extent, private knowledge.

The last point relates to the autonomous decision-making layers. Famous case studies of cartels in leading economics journals often describe in detail the mechanisms applied but not *how* these mechanisms have been concluded (see, e.g., Asker, 2010; Pesendorfer, 2000; Röller & Steen, 2006). An exception is the work of Igami and Sugaya (2022) on the global vitamin cartels in the 1990s. They mention that the agreements were developed on the firms’ top-level boards but reviewed on lower levels by different agents at different meetings. It highlights that there may exist several vertically related decision centers that have some autonomy over how defined targets shall be reached. However, a hierarchy continues to exist as it is hardly imaginable that middle managers possess the same authority to decide crucial issues as the top management level does.

Nevertheless, there may still be autonomy in the sense that the firms themselves constitute such decision centers. Even if there may exist some central entity organiz-

ing meetings or information exchange, every firm is independent in the sense that it autonomously decides whether to stick to the collusive or to deviate. For example, various research has shown that the discount factor measuring a firm's valuation of future profits is crucial to the stability of a cartel, and every cartel is only as stable as its 'weakest' member, i.e., the firm with the lowest discount factor. It assigns even to smaller firms much power over the stability of a cartel. Hence, the distribution of power in cartels can be understood as '*primus inter pares*' or else 'first among equals' power in the sense that larger firms may be a 'primus' but always among equals in the sense as every member can break the cartel. No firm can overrule this in a legally binding sense. Put differently, autonomy concerning cartels can be understood as 'mutually assured destruction.' Thus, polycentric power stems from the absence of legally binding contracts, given the illegality of such undertakings.

Institutional/cultural framework: The second and third building blocks are much easier to confirm within cartels. Regarding the institutional framework, Aligica and Tarko (2012) highlight the overlapping systems of rules present in a polycentric structure. This is clearly the case. They name incentive compatibility, which is one cornerstone of cartels. Furthermore, there are often multiple jurisdictions – formal ones in the countries where the firms are based or active as well as informal, moral jurisdictions, as cartels are, in general, illegal. Thus, the involved agents may feel the urge to justify their behavior before themselves or bystanders who know about the illegal activities.

Third, the agents are directly involved in the rule design as they define the mechanisms of what to do in case some business targets are not met or when someone deviates from an agreement. The collective choice is more involved as it depends on the specific cartel in charge and whether there is a majority or consensus rule. However, due to the '*primus inter pares*' situation the firms find themselves in, full majority rule seems risky in light of the options of everyone to deviate from the agreement or even to use the omnipresent leniency schemes to disclose the whole cartel.

Spontaneous Order: The last block of the polycentricity concept is some spontaneous order and evolutionary competition. It comprises three aspects: Entry, exit, and information. All of them are crucial issues for business cartels. ‘Entry’ has two dimensions: The initial entry when forming the cartel. This already is an essential evolutionary and hitherto non-examined topic as it is unclear how firms contact each other to form a cartel, whether it happens publicly during association meetings or bilaterally, e.g., during fairs or privately. Once a cartel establishes itself, it is an open question how the cartel members deal with either left-out market participants or new market entrants. The global vitamin cartels highlight how endogenous this issue is as the artificially high prices for vitamins triggered the emergence of new competitors (Igami & Sugaya, [2022](#)).

The opposite is true for any exit from the cartel. As mentioned earlier, two options exist. Either a cartel deviates or approaches competition authorities. Theoretically, a firm could also leave a collusive agreement without taking further action. However, this appears as a weakly dominated option as the activities within a cartel remain illegal even after leaving it. Hence, approaching competition authorities under full leniency is always weakly better than doing nothing. Of course, this depends on non-monetary ties between the cartel members and the actual design of the leniency scheme. Last, there must be some information involved, either publicly or privately. It is certainly the case given the data on sales, production capacities, and, of course, the level of future orientation the cartel members have.

In contrast to these three pillars, Aligica and Tarko ([2012](#)) point out three major potential breakages for polycentric structures. Besides the trivial fact that a cartel may become meaningless because its purpose disappears, e.g., by new regulation or a shrinking market, two issues are that the exchange of opinions does not happen anymore or the structure becomes hierarchic. Related to rules, the structure obviously tends to collapse in case the rules are questioned and are not altered, or else the agreement itself gets questioned. In cartels, a new board or new shareholders that

want to change the conduct of their firm could be a cause for it. Last, Aligica and Tarko (2012) mention a breakdown of the rule of law. While this makes sense in the context of public administration, cartels operate outside the legal sphere. But it could be related to the emergence of hierarchies within a cartel.

Regarding a breakdown caused by the third pillar, the spontaneous order and evolutionary competition issues, the aspect of ‘no entry’ seems to be crucial as cartels generate supernormal profits that may attract other firms to enter the market. Here, it can be vital for the cartel to incorporate the newcomers into the existing collusive agreement. The case of the vitamin cartels, later on, exemplifies how the inability to incorporate new members into an existing collusive agreement may lead to a collapse of this polycentric order. The other two points raised by Aligica and Tarko (2012) are also applicable: Missing information to maintain the cartel is an issue that may occur and be particularly crucial in case cartel members withhold information because they mistrust each other.

Last, the authors state as a hurdle that the ‘constituency of the system is unclear,’ which means some ambiguity over who is part of the structure and who is not. It is unlikely for cartels as they are usually a distinct circle of involved agents that have to ensure the privacy of their undertaking as it is (in most countries and, in my case, by definition) illegal. In turn, every member should know who is a member. However, once the cartel decides to involve intermediaries such as business associations, e.g., for concealed information sharing, such clear distinctions might vanish, such that a collapse of a polycentric cartel may be realistic, for example, if some member erroneously treats a business association as a member and shares insider knowledge, which may cause the association to approach authorities to be not sued as a confidant.

3 Mapping drivers of cartel failure and success

In industrial organization literature, plenty of studies investigate disclosed cartels, either directly or via a general collusive mechanism that has been in place in a detected collusion case. Levenstein and Suslow have published important review articles on cartels on drivers of success (2006) and reasons for their failure (2011). In general, the authors define three crucial tasks for cartels: Coordination, cheating, and entry (Levenstein & Suslow, 2006, p. 85). Besides these internal factors, exogenous economic shocks affect cartels only if they occur very suddenly, while cyclical demand fluctuations seem not to affect cartel stability. Concerning the internal factors, the authors name coordination in response to an altered economic environment as well as the entry of new competitors as the two primary breakpoints of cartels.

Regarding coordination, Levenstein and Suslow (2011) find in their ‘failure paper’ that cartels with compensation schemes are much more stable than those who punish their members for deviations from the collusive agreement. Related to the economic conditions, both authors find variations in firm-specific time discounting are much more influential than exogenous variation in interest rates, which constitutes some generic future discounting. It not only emphasizes the role the individual discount factors play (as outlined by Schmal, 2022a), it also offers various relations to polycentricity analysis.

First and foremost, it is crucial to note that the fragile balance created by the intra-cartel compensation and maintenance systems to explore the common pool resource of excess profits suits the definition of overlapping decision centers, at least for large companies, very well. While the cartel ‘as such’ is the overall body, it consists of the firms as entities that cooperate and compete simultaneously. Furthermore, nested within these firms are the different managerial layers with their own ties and organizational rivalries, which are common, especially in multinational firms (see, e.g., Becker-Ritterspach & Dörrenbächer, 2011; Birkinshaw & Lingblad, 2005; Bouquet & Birkinshaw, 2008).

Relating to the vitamin cartels,² one can see that firms took different roles within the organization of the collusive agreement: According to process files of the European Commission (2003), it was then also Roche representatives that contacted Eisai in 1989. Later on, Roche was the critical intermediary between Europe and Asia as it was solely Roche that held contact with Eisai directly and represented all three European firms (see paras 234 - 239, *ibid*). Hence, the outcome of a successful set-up of the cartel in Europe led Roche to extend the number of actors by involving Eisai as a non-European member. An apparent parallel can be found in the Vitamin C cartel that consisted of the European members Roche, BASF, and Merck. Again, it was Roche that contacted a Japanese firm, namely Takeda, and had a similar arrangement as a transmitter between the European cartel members and Takeda, whose officials mostly met and communicated bilaterally with Roche officials as stated in the report of the European Commission (2003, paras 415 - 417): “Takeda refused to attend multilateral cartel meetings with BASF and Merck but held ‘one-to-one’ meetings with Roche.” It is strong evidence for the presence of multiple decision centers.

As Aligica and Tarko (2012) note, polycentric orders collapse once they get hierarchical, and the multiplicity of decision centers disappear. This may be the reason why cartels with sophisticated compensation schemes are more resilient (Levenstein & Suslow, 2006). Even though such methods leave more traces and underline the criminal intentions of the actors involved – which should, *ceteris paribus*, make the use of the ‘emergency exit’ of leniency options more attractive – such compensation schemes require maintenance and by that, the involvement of more agents and decision centers. In contrast, very plain cartels that can be arranged solely by one decision layer or are fixed by one leading firm may be rather monocentric. The same holds for incorporating

²The vitamin cartels were multiple cartels separated by the vitamins produced. In total, 16 collusive agreements existed, coordinating the sales of the vitamins A, E, B1, B2, B3, B5, B6, B12, C, D3, H, choline chloride, feed premix, folic acid, beta-carotene, and corticoids (Connor, 2006). While some of the separate cartels collapsed independently, others endured until the US Department of Justice and the European Commission (EC) took legal steps against them Igami and Sugaya (2022). The cartels were organized by sales quotas mutually assigned during conspiratorial meetings. At that time, the market leaders as well as the leading firms within the cartels were Roche, BASF, and Rhone-Poulenc, now part of Sanofi (European Commission, 2003).

a third party into the cartel governance, for example, a business or trade association. These institutions may serve as essential clearing centers of information, such as actual prices and sales of the participants. However, they also centralize communication and decision-making, which may lead to monocentric governance structures within a cartel. It, in turn, may destabilize a cartel in the long run.

Of course, one should not ignore that such schemes may also raise stability as they may adjust for asymmetries between the cartel members in terms of future orientation, market shares, or cost structures (Levenstein & Suslow, 2011). Furthermore, such schemes may foster trust among the participants, a core ingredient of cartels (Leslie, 2003) and collective action in general (Ostrom, 1998). Both reasons may be related to polycentricity in so far as it not only accounts for the dispersion of knowledge within firms. It may also have a calming effect on the managers in charge as they can be sure that other divisions in their organizations with better information or knowledge of the topic are responsible for a particular issue. By taking away the pressure of the necessity to handle everything, polycentric collusive structures may foster trust in one's own capability to stick to the agreements as well as in the mutual managers of the other firms involved. Put differently, the power of polycentricity in this context can be subsumed as a 'divide and impera' concept that distributes responsibilities and, by that, allows every individual involved to focus on her or his very own tasks.

The second sensitive topic for cartel stability is the entry of new competitors (Levenstein & Suslow, 2011). This threat always exists in markets but is particularly relevant for markets with solid cartels operating in them, as overly high prices are an endogenous accelerator of market entry. Ostrom (1999, p. 59) stated that the *"viability of the market as a polycentric ordering will depend upon whether individuals have incentives to organize firms that will be effective participants in such a market ... and whether such firms are free to enter the market and engage in trade."* While it is conceivable that new market participants are interested in participating in the incumbent cartel, the opposite may not hold. Cartels, as well as oligopolistically organized markets, often

engage in driving new entrants out of their market (see, e.g., Asker & Bar-Isaac, 2014; Lerner, 1995; Morton, 1997).

On the other hand, cartels also try to approach existing or new competitors in their market to join their cartel. Thus, entry is possible. Furthermore, exit from a cartel is also conceivable. However, the challenge of existing traces exists as well as the leniency option: If a firm leaves a cartel, its former cartel members may still possess compromising evidence of the period in which the leaving firm was active in the cartel. Furthermore, a firm leaving a cartel may scare the other participating firms and managers, of whom one or more could use the often-offered leniency schemes to disclose the cartel to the authorities under the condition of impunity. Hence, exiting a cartel may be difficult but possible, especially in changing market environments.

4 Exploratory empirical evidence

By construction, analyses on business cartels and collusive practices come with many hurdles as they usually operate illegally. Furthermore, severe sample selection exists as only detected cartels can be studied by definition.³ Switching to legal cartels, as, for example, Forsbacka et al. (2023) do, is not an alternative as such cartel agreements can rely on legal structures and enforcement mechanisms. It severely alters the setting in which the involved agents find themselves. Therefore, I rely on the scarce data on illegal but disclosed collusion cases. I use the OECD cartel database that includes 191 unique cartels that have been discovered between the years 2012 - 2018.⁴ This dataset bears the advantage of including rather recent cartels and a comparatively large number of cases. Overall, this is still a rather small number of observations, and I am also only able to discuss some correlational evidence here in this paper. However, given the exploratory character of it, it may still be informative.

³However, it is not clear whether this is a major distortion or to which extent disclosed cartels may be representative for the whole body of cartels (see, e.g., Harrington & Wei, 2017).

⁴See for more information https://qdd.oecd.org/subject.aspx?Subject=OECD_HIC.

Cartel Members and Duration: First of all, Table 1 below shows that there exists actually a positive relationship between the number of colluding firms within a cartel and its duration.⁵ Using a parsimonious OLS estimation, one gets a coefficient of 0.12, which implies that for each additional cartel member, the average duration of the collusive agreement was 1.44 months longer. Figure 1 below depicts this.

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.1165	0.0698	1.67	0.097	0.0010	0.2319
Constant	4.9785	0.5677	8.77	0.000	4.0396	5.9175

Estimation method: LPM (linear probability model). Dependent variable: Cartel duration in years. Standard errors heteroskedasticity-robust. $N = 168$. $F(1, 166) = 2.79$, $Prob > F = 0.097$, $R^2 = 0.0246$. Table A7 in the appendix presents the results for the corresponding jackknife estimation.

Table 1: Relationship between the number of cartelists and cartel duration

The finding is counterintuitive given the basic game theoretic modeling of cartels as done, e.g., in the graduate textbook of Varian (1992). Here, it is usually proposed that more firms destabilize the cartel as the deviation profit increases in the number of cartel members relative to each participant’s collusive profit. It is simply because, with more participants, one’s own share decreases while the deviation profit remains approximately the same.

However, in light of a polycentric order, the positive correlation may be reasoned. An increase in members could stabilize a cartel as more members allow for a more dispersed assignment of responsibilities as well as more mutual interdependencies that are less likely in a, say, two- or three-firm setting. To ensure that my results are valid, I conduct a jackknife estimation, which works via reestimating the regression N times while leaving out each observation once. This method is more conservative in estimating standard errors than bootstrapping and particularly applies to small samples (Efron, 1982). Here, it helps to net out the effect of outliers in the data, which

⁵Fig. F1 presents descriptive statistics on this variable. Overall, the average number of cartel members is 7.27, the median is 5, the 90th percentile is 15, the 99th percentile is 35, and the highest observation in this dataset is 38 members of a single collusion case, namely the modeling agency cartel in France, that was convicted of price fixing for fashion shootings and related services, see, e.g., <https://www.lexology.com/library/detail.aspx?g=0b6803af-fb95-41fe-ab6b-20422bfc86e>.

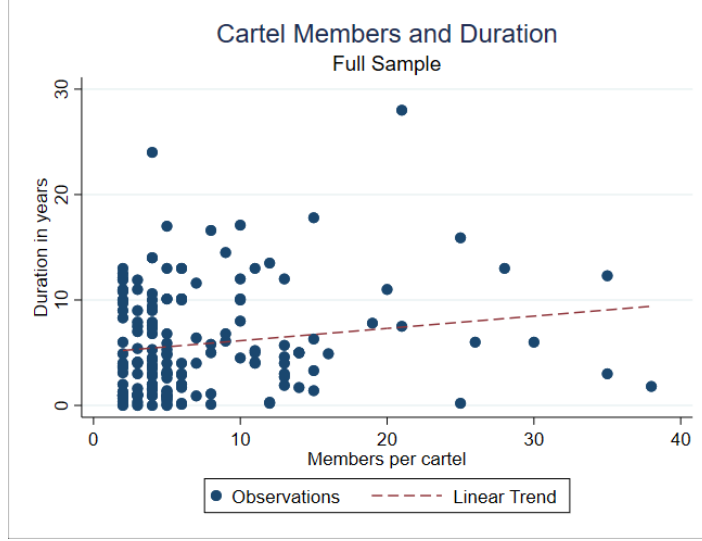
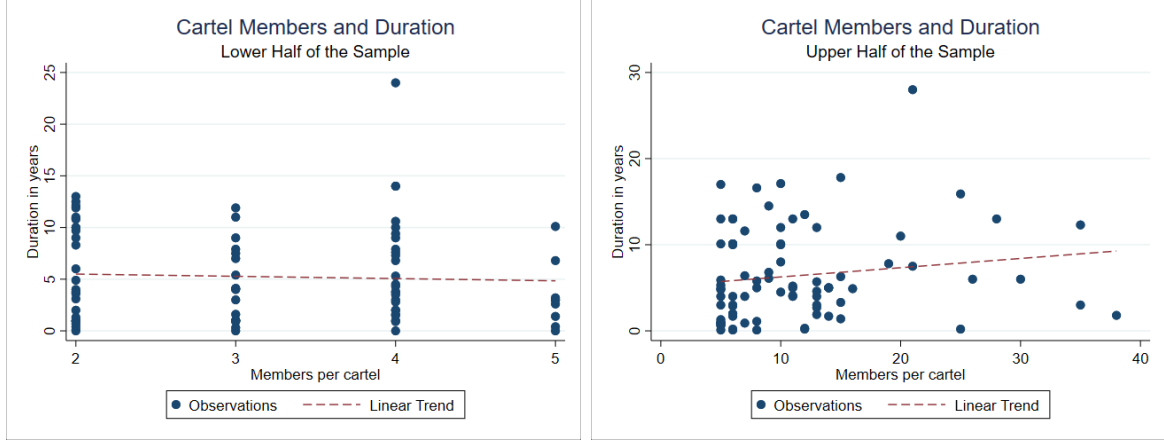


Figure 1: Scatter plot for the relation between cartel members and duration

is important to ensure that specific cartels do not drive the results. Table A7 presents the results for the first regression using the jackknife estimation. One can see that the positive coefficient for the number of cartel members becomes statistically insignificant also on the 10% level. It emphasizes that one should interpret the result from Table 1 carefully. However, it remains a notable fact that the coefficient for the number of cartel members is *not* negative. Hence, even if more cartel members do not have a significantly positive impact on cartel duration, they also do not harm how long cartels exist. This is still in conflict with established theory.

One data-driven objection to this finding might be the potential risk that cartel duration is easy to measure at the endpoint but not at the starting point. Here, the data rely on legal investigations and court decisions, thus, highly reliable data. However, investigators are not always able to prove the existence of a cartel years ago legally, mainly if no clear records exist (see also Zhou, 2016). Thus, cartel duration could be, in reality, longer than in the data. As long as this left-truncation is idiosyncratic, this is acceptable. However, it may bias the dataset if the lack of evidence occurs more often among smaller cartels as they could be more able to hide and delete evidence than larger cartels, where more firms exist that could (in)voluntarily provide the necessary evidence.



The left panel shows a scatter plot for the relation between cartel members and duration using only the lower half of the sample as measured by the size of the cartel. The right panel accordingly shows a scatter plot using only the upper half of the sample. As the median value of $\tilde{C} = 5$ occurs in 29 cases, the 29 observations have been assigned to the lower/upper half based on a random normal variable that has been sorted in ascending order. For the distribution of the random variable, see Fig. F2 in the appendix. For the regression results of the linear regression, see Tables A5 (LHS) and A6 (RHS) in the appendix.

Figure 2: Scatter plot for the relation between cartel members and duration: Sample split

Figure 2 presents two panels that plot the relation between the number of cartel members and its duration. The left panel shows the distribution of the lower half of the dataset, i.e., those observations with cartel participants up to the 50th percentile of the distribution of this variable, the right one only presents data for the upper half of the distribution.⁶ For small cartels with 2 - 5 members, there appears to be a slight negative relationship between the number of members and cartel duration. The right panel, including cartels with five or more members, presents an upward trend. However, when splitting the regressions in the same way as the data for the scatter plots, neither the negative nor the positive linear trend is significantly different from zero. This is in favor of the insignificant jackknife estimation. As said, the null effect remains a puzzling finding by itself.

A last objection to the analysis is again data-driven and concerns the evolution of the size of a cartel. It could be the case that only very few firms initiated a cartel,

⁶As the median value of $\tilde{C} = 5$ occurs in 29 cases, the 29 observations have been assigned to the lower/upper half based on a random normal variable that has been sorted in ascending order. For the distribution of the random variable, see Fig. F2 in the appendix. The seed for the generating process is 1896 to ensure replicability. Alternative seeds would lead to a slightly different sorting, which does not alter the findings qualitatively.

but several other firms may have joined it over time. When detected, only one value for the number of cartel members is registered, and it is likely the number recorded at detection. Thus, empirically assuming that the value at the end equals the one at the beginning might distort the analysis. Even though I cannot resolve this issue with the given data, there is at least suggestive evidence that cartel entry is not as relevant as cartel exit when looking at publications in the leading journals in industrial economics. Furthermore, it is unlikely that many firms joined an existing cartel. It is more likely that only very few were added over time due to the risks attached to it and the complicated procedures of integrating a new member if grown governance and trust structures. It is more likely that existing firms try to deter market entrance in general (Levenstein et al., 2016).

Cartel members and sanctions: In a similar direction goes the relation between the number of cartel members and the subsequent sanctions. In theory, more members should lead to an increase in the fines imposed when a cartel is detected. However, besides this first-order effect, it is unclear in which direction any second-order effect points. A linear relation would be conceivable given that more participants also require a larger fine as every member needs to be punished. Furthermore, the welfare losses caused by a cartel with a larger number of members should be, all things equal, larger than a cartel in the same market with a lower number of participants. In that sense, even an increase in sanctions, which is larger than proportional, would be reasonable. It is backed by the regressive nature of the leniency regulation: As Connor (2012) notes, nearly all recent major cartel cases ended with full or partial leniency for at least one former cartel member. So, if the fine f per member is fixed, such that the total amount of sanctions imposed on all cartel members C jointly is $F = Cf$, leniency for one participant leads to $F = (C - 1)f$. For the average fine $\bar{f}$, it must hold that

$$\bar{f} = \frac{(C - 1)f}{C} \quad \rightarrow \quad \frac{\partial}{\partial C} \bar{f} = \frac{f}{C^2} > 0$$

It follows straight away that $\bar{f}$ increases in the number of cartel members (as long the number of leniency grants remains stable). This setting suggests even a convex relationship between the number of cartel members and the amount of sanctions.

Table 2 depicts the actual relation found in the OECD database. Besides the linear effect, it also includes a coefficient for the quadratic term, which is important: The sanctions imposed on the cartel members increase in the number of participants. However, this is not a linear increase but offset by a negative quadratic effect.⁷

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	15.5839	6.5696	2.37	0.019	4.7214	26.4464
#Cartelists ²	-0.4652	0.1850	-2.51	0.013	-0.7711	-0.1593
Constant	-9.8593	22.4962	-0.44	0.662	-47.0559	27.3372

Estimation method: LPM. Dependent variable: Sanctions in million USD. Standard errors heteroskedasticity-robust. $N = 181$. $F(2, 178) = 3.53$, $Prob > F = 0.0314$, $R^2 = 0.0508$. Table A8 in the appendix presents the results for the corresponding jackknife estimation.

Table 2: Relationship between the number of cartelists and sanctions

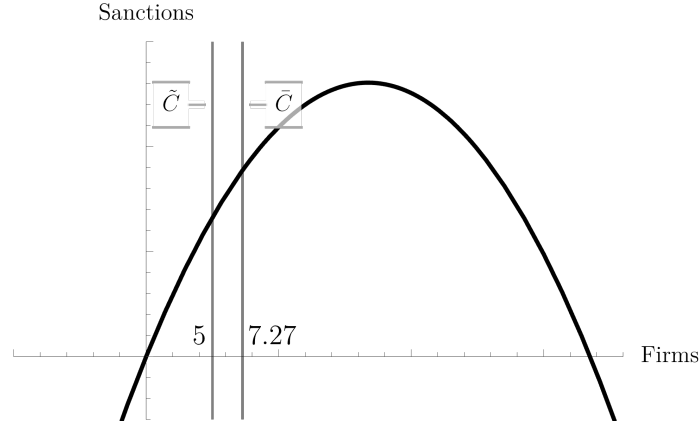
Together, the two estimates imply a concave relationship between the number of cartel members and the total amount of sanctions. It corresponds to a negative relationship between the number of participants and the average amount of sanctions per participant ($\bar{f}$) as Table A3 in the appendix shows.⁸ Figure 3 illustrates this concave relation. Given the distribution of the cartel member variable, it is, of course, clear that most cartels are in the area with a positive slope. However, there exist several cartels with a large number of participants that got comparatively low sanctions.

Even though there exists no ‘smoking gun’ evidence, polycentricity, again, is likely to be a driver of this statistical artifact. The more participants a cartel has, the more dispersed decision centers and layers can be. Put differently, it may be more challenging for competition authorities to prove who was responsible for specific illegal activities.

⁷One can also model the relationship with a polynomial of order three, as done in Table A2 and Fig. F3. Here, one can see that the functional form in the relevant range of the number of cartel members is highly similar to the quadratic specification.

⁸It also holds for polynomial specification of order 2, i.e., with an additional quadratic term. Here, both coefficients are separately insignificant but jointly highly significant ($F(2, 178) = 7.57$, $p = 0.0007$), see Table A4 in the appendix.

Relationship: Cartelists and Sanctions



$\tilde{C}$ = median cartel members, $\bar{C}$ = mean cartel members. Plot of the coefficients as computed in Table 2. Constant omitted due to statistical insignificance.

Figure 3: Relationship between cartel members and sanctions: Quadratic specification

Take the global vitamin cartels as an example of such a dispersed system of decision layers. There existed four councils in the cartels differentiated by a hierarchy that were responsible for the agreement on quotas, the practical implementation, and the surveillance of the actual sales (Connor, 2008). While, for example, Martin and Schmal (2021) explain sophisticated cartel organization with its arguably beneficial impact on raising the future orientation (technically, it is the critical discount factor) of participating *firms*, it might also be reasoned by the sociological phenomenon of ‘shifting the blame.’ As argued by Fiorina (1982, 1986) and Vaubel (1986), politicians have an interest in delegating unpleasant tasks and the responsibility for bad decisions to other agencies in the public body. A polycentric order of a collusive structure could reflect this behavior.

The system of four different decision layers might serve not only as a top-down delegation system but also as a sharing of responsibilities so granular that every participant may consider themselves only as a small part of a larger system, which may reduce the potential burden of doing something illegal as well as the actual ability of legal authorities to assign particular actions to specific agents or firms. Hence, polycentricity may serve as a protection against legal action since dispersed decision-making processes make it more difficult to assign responsibilities in a legally binding way.

The impact of third party involvement: In the last step, I want to look at the role of third parties in a collusive structure. Frequent examples are trade or industry associations that facilitate unobtrusive coordination. They also often allow their members to track sales of other members by collecting and aggregating information. By doing so, such third parties are often considered a stabilizing element in cartels (see, e.g., Levenstein & Suslow, 2006). Using the OECD database of recent cartels, I cannot confirm that. It is not surprising that the likelihood of the involvement of a third party increases in the number of cartel participants, as Table 3 below shows. Here, such an institution serves simply as a coordination device.

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.0767	0.0169	4.55	0.000	0.0490	0.1045
Constant	-2.1242	0.2344	-9.06	0.000	-2.5098	-1.7386

Estimation method: Probit model. Dependent variable: Binary indicator for the presence of a third party. $N=181$. $\chi^2(1) = 20.66$, $Prob > F = 0.0000$, Pseudo $R^2 = 0.1979$. Table A9 in the appendix presents the results for the corresponding jackknife estimation.

Table 3: Relationship between the number of cartelists and the presence of a third party

Crucially, however, I cannot detect an effect of such a third party on cartel duration as Table 4 demonstrates. With a t-statistic of 1.58, the positive coefficient is insignificant on any level. Levenstein and Suslow (2011) detect in their analysis of cartel deaths that third parties increase the risk of being caught but, on the other hand, stabilize the cartel. These two effects could offset each other in the given sample. An up-to-now overlooked issue in this regard is that the implementation of, e.g., a business association is a monocentric element in a cartel. It (consciously) centralizes communication and coordination. By that, it collides with two core principles of polycentricity as presented in Section 2. First, the ‘multiplicity of decision centers’ is reduced when everything is centered around a business association and its meetings.

Furthermore, such an institution undermines spontaneous order. A central organization, by definition, collects a large amount of data that may serve as evidence for

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
$\mathbb{1}_{Third\ Party}$	2.9027	1.8328	1.58	0.115	0.7147	6.5202
Constant	5.5901	0.3729	14.99	0.000	4.8540	6.3260

Estimation method: LPM. Dependent variable: Cartel duration in years. $N = 176$. $F(1, 174) = 2.51$, $Prob > F = 0.1151$, $R^2 = 0.0250$. Table A10 in the appendix presents the results for the corresponding jackknife estimation.

Table 4: Relationship between cartel duration and the presence of a third party

competition authorities if detected. Furthermore, leaving a cartel that encompasses a business association raises doubts about to which extent the leaving member is still welcome there. Even if a firm leaves a collusive agreement, it remains a part of the industry and, probably, of a business or trade association, as such organizations tend to be monopolies in their respective branch of the economy. This monocentric organization implies that leaving the cartel is only possible when the cartel as a whole breaks down, which, in turn, is an incentive for the firm, which is willing to leave, to apply for a leniency scheme. Such a scheme, however, will destroy the cartel as a whole – a consequence that could be avoided if a participating firm could leave a cartel without facing such problems.

I argue that monocentricity is the underlying destabilizing factor of cartels relying on a third party that serves as a communication and coordination institution. In general, polycentric governance may be a novel explanation for the ‘puzzle of plenty,’ i.e., for the question of why there exist so many cartels with a large number of participants, even though economic theory would suggest much more instability for collusive structures with such a high amount of members. Previous research in this domain has primarily focused on external factors, such as market characteristics, that may have led to relative stability despite the large size of cartels. This paper does not question this work but adds an organizational perspective to explain this puzzle better.

5 Conclusion

Collusive agreements are a puzzling phenomenon. Firms enter into legally unenforceable contracts. They can be betrayed at any time, either through leniency agreements or defection from the collusive sales agreements, but are nevertheless often stable for years. Thus, it is reasonable to conclude that business cartels are governance systems with multidimensional interrelations and incentive constraints. The concept of polycentric governance offers novel ways to understand the coordination within a cartel between firms. As derived theoretically, organizing the governance of such an illegal agreement among firms and their agents with a polycentric structure is likely a driver of success that has been, up to now, widely overlooked in this domain.

Applying the concept to an extensive OECD dataset of detected cartels, polycentricity can explain several empirical phenomena. On the one hand, there seems to be no negative relationship between the number of cartel members and its duration. In addition, sanctions imposed on the participants of a cartel follow an inverse-u pattern. Fines increase underproportionally with the rise in members. Lastly, even though huge cartels often involve third parties in their activities for coordination and communication reasons, such entities do not stabilize a cartel in duration. All three empirical findings can be explained with polycentric governance or the lack of it.

By that, the paper shows how political and institutional theory can fruitfully enrich the understanding of (industrial) economic phenomena. By that, it virtually goes in the opposite direction as Downs (e.g., in his *JPE* publication from 1957), who used economic, in particular, industrial economic theory to understand the behavior of government and parties in a democracy. This paper is meant to be the first step toward both broader and deeper implementation of institutional, political, and public choice theory back into the field of industrial organization to understand better the behavior of firms, which ultimately consist of humans and hierarchies that are often far away from acting benevolent for the organization and often only partially profit maximizing.

References

- Acharya, V. V., S. C. Myers, and R. G. Rajan (2011). "The Internal Governance of Firms". In: *The Journal of Finance* 66.3, pp. 689–720.
- Aligica, P. D. (2015). "Public administration, public choice and the Ostroms: The achievements, the failure, the promise". In: *Public Choice* 163.1, pp. 111–127.
- Aligica, P. D., P. J. Boettke, and V. Tarko (2019). "Polycentric Stakeholder Analysis: Corporate Governance and Corporate Social Responsibility". In: *Public governance and the classical-liberal perspective: Political economy foundations*. Oxford University Press.
- Aligica, P. D. and V. Tarko (2012). "Polycentricity: from Polanyi to Ostrom, and beyond". In: *Governance* 25.2, pp. 237–262.
- Ammann, M., D. Oesch, and M. M. Schmid (2011). "Corporate governance and firm value: International evidence". In: *Journal of Empirical Finance* 18.1, pp. 36–55.
- Asker, J. (2010). "A Study of the Internal Organization of a Bidding Cartel". In: *American Economic Review* 100.3, pp. 724–62.
- Asker, J. and H. Bar-Isaac (2014). "Raising retailers' profits: On vertical practices and the exclusion of rivals". In: *American Economic Review* 104.2, pp. 672–86.
- Bebchuk, L. A. and A. Cohen (2005). "The costs of entrenched boards". In: *Journal of Financial Economics* 78.2, pp. 409–433.
- Becker-Ritterspach, F. and C. Dörrenbächer (2011). "An organizational politics perspective on intra-firm competition in multinational corporations". In: *Management International Review* 51.4, pp. 533–559.
- Bhagat, S. and B. Bolton (2008). "Corporate governance and firm performance". In: *Journal of Corporate Finance* 14.3, pp. 257–273.
- Birkinshaw, J. and M. Lingblad (2005). "Intrafirm competition and charter evolution in the multibusiness firm". In: *Organization science* 16.6, pp. 674–686.
- Bouquet, C. and J. Birkinshaw (2008). "Weight versus voice: How foreign subsidiaries gain attention from corporate headquarters". In: *Academy of Management journal* 51.3, pp. 577–601.
- Brams, S. J. (2006). "The Normative Turn in Public Choice". In: *Public Choice* 127.3/4, pp. 245–250.
- Brown, L. D. and M. L. Caylor (2006). "Corporate governance and firm valuation". In: *Journal of Accounting and Public Policy* 25.4, pp. 409–434.
- Connor, J. M. (2006). "The great global vitamins conspiracy: Sanctions and deterrence". In: *American Antitrust Institute Working Paper* 06-02.
- Connor, J. M. (2012). "Cartel fine severity and the european commission: 2007-2011". In: *European Competition Law Review* 34.2013, pp. 58–77.
- Connor, J. M. (2008). *Global Price Fixing*. 2nd updated and revised edition. Vol. 26. Studies in Industrial Organization. Berlin: Springer.
- Dick, A. R. (1996). "When are cartels stable contracts?" In: *The Journal of Law and Economics* 39.1, pp. 241–283.
- Downs, A. (1957). "An Economic Theory of Political Action in a Democracy". In: *Journal of Political Economy* 65.2, pp. 135–150.

- Efron, B. (1982). *The jackknife, the bootstrap and other resampling plans*. CBMS-NSF Regional Conference Series in Applied Mathematics. Philadelphia, PA: Society for industrial and applied mathematics (SIAM).
- European Commission (2003). “Case COMP/E-1/37.512 - Vitamins”. In: *Official Journal of the European Communities* L6, pp. 1–87.
- Fiorina, M. P. (1982). “Legislative choice of regulatory forms: Legal process or administrative process?” In: *Public Choice* 39.1, pp. 33–66.
- Fiorina, M. P. (1986). “Legislator Uncertainty, Legislative Control, and the Delegation of Legislative Power”. In: *Journal of Law, Economics, and Organization* 2.1, pp. 33–51.
- Forsbacka, T., C. Le Coq, and C. Marvão (2023). “Cartel birth and death dynamics: Empirical evidence”. In: *International Journal of Industrial Organization*, p. 102932.
- Gompers, P., J. Ishii, and A. Metrick (2003). “Corporate governance and equity prices”. In: *The Quarterly Journal of Economics* 118.1, pp. 107–156.
- Harrington, J. E. and Y. Wei (2017). “What can the duration of discovered cartels tell us about the duration of all cartels?” In: *The Economic Journal* 127.604, pp. 1977–2005.
- Harrington, J. E. and A. Skrzypacz (2011). “Private Monitoring and Communication in Cartels: Explaining Recent Collusive Practices”. In: *American Economic Review* 101.6, pp. 2425–49.
- Haucap, J. and C. Heldman (2023). “The Sociology of Cartels”. In: *European Journal of Law and Economics* 56, pp. 289–323.
- Haucap, J., C. Heldman, and H. A. Rau (2023). “Gender and Cooperation in the Presence of Negative Externalities”. In: *CESifo Working Paper 9614*. Updated version January 2023.
- Huck, S., H.-T. Normann, and J. Oechssler (2004). “Two are few and four are many: number effects in experimental oligopolies”. In: *Journal of Economic Behavior & Organization* 53.4, pp. 435–446.
- Hyttinen, A., F. Steen, and O. Toivanen (2019). “An anatomy of cartel contracts”. In: *The Economic Journal* 129.621, pp. 2155–2191.
- Igami, M. and T. Sugaya (2022). “Measuring the Incentive to Collude: The Vitamin Cartels, 1990–99”. In: *The Review of Economic Studies* 89.3, pp. 1460–1494.
- Lerner, J. (1995). “Pricing and financial resources: an analysis of the disk drive industry, 1980–88”. In: *The Review of Economics and Statistics*, pp. 585–598.
- Leslie, C. R. (2003). “Trust, distrust, and antitrust”. In: *Texas Law Review* 82, p. 515.
- Levenstein, M. C., C. Marvão, and V. Y. Suslow (2016). “Preventing cartel recidivism”. In: *Antitrust* 30 (3), pp. 81–88.
- Levenstein, M. C. and V. Y. Suslow (2006). “What Determines Cartel Success?” In: *Journal of Economic Literature* 44.1, pp. 43–95.
- Levenstein, M. C. and V. Y. Suslow (2011). “Breaking Up Is Hard to Do: Determinants of Cartel Duration”. In: *The Journal of Law and Economics* 54.2, pp. 455–492.
- Martin, S. and W. B. Schmal (2021). “Collusive Compensation Schemes Aided by Algorithms”. In: *CESifo Working Paper 9481*.
- McPhail, E. and V. Tarko (2017). “The evolution of governance structures in a polycentric system”. In: *Handbook of Behavioural Economics and Smart Decision-Making*. Ed. by M. Altman. Edward Elgar Publishing, pp. 290–314.

- Morton, F. S. (1997). "Entry and predation: British shipping cartels 1879–1929". In: *Journal of Economics & Management Strategy* 6.4, pp. 679–724.
- Ostrom, E. (1998). "A behavioral approach to the rational choice theory of collective action: Presidential address, American Political Science Association, 1997". In: *American political science review* 92.1, pp. 1–22.
- Ostrom, E. (2005). "Robust Resource Governance in Polycentric Institutions". In: *Understanding Institutional Diversity*. Princeton University Press, pp. 32–68.
- Ostrom, V. (1999). "Polycentricity (part 1)". In: *Polycentricity and Local Public Economies*. Ed. by M. D. McGinnis. University of Michigan Press, Ann Arbor, MI, pp. 52–74.
- Ostrom, V., C. M. Tiebout, and R. Warren (1961). "The organization of government in metropolitan areas: a theoretical inquiry". In: *American Political Science Review* 55.4, pp. 831–842.
- Pesendorfer, M. (2000). "A study of collusion in first-price auctions". In: *The Review of Economic Studies* 67.3, pp. 381–411.
- Röller, L.-H. and F. Steen (2006). "On the workings of a cartel: Evidence from the Norwegian cement industry". In: *American Economic Review* 96.1, pp. 321–338.
- Schmal, W. B. (2022a). "Governing the Cartels – an Institutional Exploration". In: mimeo.
- Schmal, W. B. (2022b). "Vice Versa: The Decoupling of Content and Topic Heterogeneity in Collusion Research". In: *available on SSRN*.
- Schwalbe, U. (2013). "Kronzeugenregelungen und die interne Struktur von Kartellen". In: *Wettbewerb und Regulierung in Medien, Politik und Märkten*. Nomos Verlagsgesellschaft mbH & Co. KG, pp. 415–440.
- Selten, R. (1973). "A simple model of imperfect competition, where 4 are few and 6 are many". In: *International Journal of Game Theory* 2, pp. 141–201.
- Shortland, A. (2018). "Governing criminal markets: The role of private insurers in kidnapping for ransom". In: *Governance* 31.2, pp. 341–358.
- Shortland, A. and A. Shortland (2020). "Governance under the shadow of the law: trading high value fine art". In: *Public Choice* 184.1-2, pp. 157–174.
- Shughart, W. F. (2022). "On the Virginia school of antitrust: Competition policy, law & economics and public choice". In: *Public Choice* 191.1, pp. 1–19.
- Smith, A. (1776/1904). *An inquiry into the nature and causes of the wealth of nations*. London, UK: Methuen & Co.
- Stephan, M., G. Marshall, and M. McGinnis (2019). "An introduction to polycentricity and governance". In: *Governing Complexity: Analyzing and Applying Polycentricity*. Ed. by A. Thiel, W. A. Blomquist, and D. E. Garrick. Cambridge University Press Cambridge, pp. 21–44.
- Stigler, G. J. (1964). "A theory of oligopoly". In: *Journal of Political Economy* 72.1, pp. 44–61.
- Varian, H. R. (1992). *Microeconomic Analysis*. 3rd ed. W.W. Norton & Company.
- Vaubel, R. (1986). "A public choice approach to international organization". In: *Public Choice* 51.1, pp. 39–57.
- Wu, H.-L. (2008). "When does internal governance make firms innovative?" In: *Journal of Business Research* 61.2, pp. 141–153.

Zhou, J. (2016). “The rise and fall of cartels with multi-market colluders”. In: *Review of Industrial Organization* 48, pp. 381–403.

6 Appendix

Variable	#Obs.	Mean	Std. Dev.	Min	Max
Cartel Duration (years)	176	5.8210	4.9797	0	28
#Cartelists	181	7.2652	6.6505	2	38
#Cartelists ²	181	96.7680	209.261	4	1,444
$\mathbb{1}_{BidRigging}$	191	0.4607	0.4998	0	1
$\mathbb{1}_{ThirdParty}$	191	0.0785	0.2697	0	1
Sanctions (mio. USD)	191	56.9905	152.9816	0	1,165.85

Table A1: Descriptive statistics of the variables in the dataset

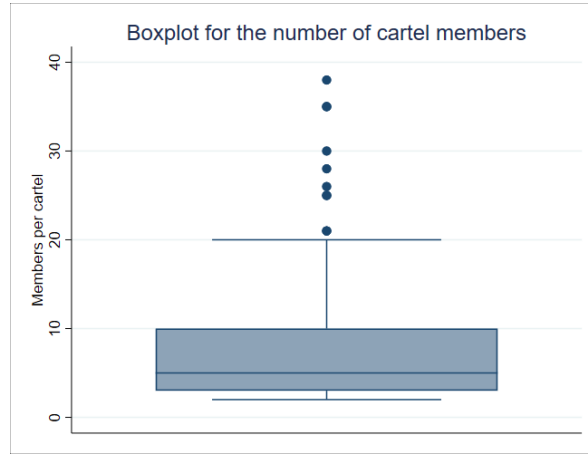


Figure F1: Boxplot for the number of members in a cartel

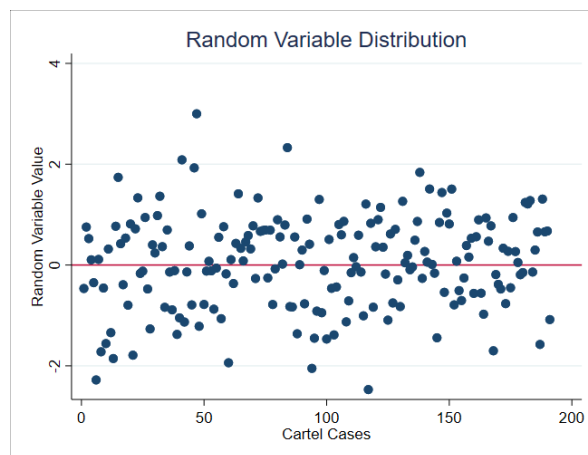
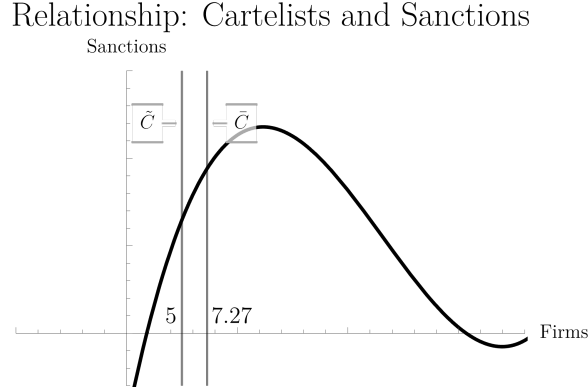


Figure F2: Scatterplot for the distribution of the random variable created for the median sample split

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	31.2519	10.1563	3.08	0.002	14.4584	48.0454
#Cartelists ²	-1.7280	0.5566	-3.10	0.002	-2.6484	-0.8076
#Cartelists ³	0.0249	0.0089	2.81	0.006	0.0102	0.0395
Constant	-51.3480	28.7646	-1.79	0.076	-98.9105	-3.7855

Dependent variable: Sanctions in million USD. Standard errors heteroskedasticity-robust. $N = 181$. $F(3, 177) = 4.84$, $Prob > F = 0.0029$, $R^2 = 0.0611$.

Table A2: Relationship between the number of cartelists and sanctions



$\tilde{C}$ = median cartel members, $\bar{C}$ = mean cartel members. Plot of the coefficients as computed in Table A2.

Figure F3: Relationship between cartel members and sanctions: Cubic specification

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	-0.2352	0.1393	-1.69	0.093	-0.5101	0.0396
Constant	11.163	2.1027	5.31	0.000	7.0146	15.3130

Estimation method: LPM. Dependent variable: Sanctions in million USD *per participant* ($\bar{f}$). Standard errors heteroskedasticity-robust. $N = 181$. $F(3, 180) = 2.83$, $Prob > F = 0.0941$, $R^2 = 0.0054$. Jackknife estimation in Table A11 below.

Table A3: Relationship between the number of cartel members and sanctions per member

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.3782	0.5952	0.64	0.526	-0.7963	1.5527
#Cartelists ²	-0.0207	0.0164	-1.26	0.208	-0.0531	0.0116
Constant	8.7137	3.0830	2.83	0.005	2.6298	14.7977

Estimation method: LPM. Dependent variable: Sanctions in million USD *per participant* ($\bar{f}$). Standard errors heteroskedasticity-robust. $N = 181$. $F(2, 178) = 7.57$, $Prob > F = 0.0007$, $R^2 = 0.0101$. Jackknife estimation in Table A12 below.

Table A4: Relationship between the number of cartelists and sanctions

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	-0.2173	0.4661	-0.47	0.642	-0.9927	0.5582
Constant	5.9297	1.5463	3.83	0.000	3.3572	8.5023

Estimation method: LPM. Dependent variable: Cartel duration in years. Standard errors heteroskedasticity-robust. $N = 84$. $F(1, 82) = 0.22$, $Prob > F = 0.6423$, $R^2 = 0.0024$. The results correspond to those shown in the left panel of Figure 2.

Table A5: Relationship between the number of cartelists and cartel duration: Lower half of sample split

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.1073	0.0887	1.21	0.230	-0.0402	0.2548
Constant	5.1884	1.0445	4.97	0.000	3.4507	6.9261

Estimation method: LPM. Dependent variable: Cartel duration in years. Standard errors heteroskedasticity-robust. $N = 84$. $F(1, 82) = 1.46$, $Prob > F = 0.2297$, $R^2 = 0.0225$. The results correspond to those shown in the right panel of Figure 2.

Table A6: Relationship between the number of cartelists and cartel duration: Upper half of sample split

Results using jackknife estimation

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.1165	0.0738	1.58	0.117	-0.0057	0.2386
Constant	4.9785	0.5823	8.55	0.000	4.0154	5.9416

Estimation method: LPM. Dependent variable: Cartel duration in years. Standard errors heteroskedasticity-robust. $N = 168$. $F(1, 167) = 2.49$, $Prob > F = 0.1166$, $R^2 = 0.0246$. The results correspond to those shown in Table 1.

Table A7: Relationship between the number of cartelists and cartel duration: Jackknife standard error computation

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	15.5839	6.7146	2.32	0.021	4.4822	26.6856
#Cartelists ²	0.193287	-2.41	0.017	-0.7848	-0.1456	
Constant	-9.8593	22.9391	-0.43	0.668	-47.7859	28.0673

Estimation method: LPM. Dependent variable: Sanctions in million USD. Standard errors heteroskedasticity-robust. $N = 181$. $F(2, 180) = 2.94$, $Prob > F = 0.0553$, $R^2 = 0.0508$. The results correspond to those shown in Table 2.

Table A8: Relationship between the number of cartelists and sanctions: Jackknife standard error computation

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.0767	0.0182	4.22	0.000	0.0467	0.1068
Constant	-2.1242	0.2528	-8.40	0.000	-2.5422	-1.7062

Estimation method: Probit model. Dependent variable: Binary indicator for the presence of a third party. $N = 181$. $F(1, 180) = 17.83$, $Prob > F = 0.0000$, Pseudo $R^2 = 0.1979$. The results correspond to those shown in Table 3.

Table A9: Relationship between the number of cartelists and the presence of a third party: Jackknife standard error computation

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
$\mathbb{1}_{Third\ Party}$	2.9027	1.9518	1.49	0.139	-0.3248	6.1303
Constant	5.5901	0.3720	15.03	0.000	4.9750	6.2052

Estimation method: LPM. Dependent variable: Cartel duration in years. $N = 176$. $F(1, 175) = 2.21$, $Prob > F = 0.1388$, $R^2 = 0.0250$. The results correspond to those shown in Table 4.

Table A10: Relationship between cartel duration and the presence of a third party: Jackknife standard error computation

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	-0.2352	0.1398	-1.68	0.094	-0.4664	-0.0041
Constant	11.163	2.1009	5.31	0.000	7.6902	14.6374

Estimation method: LPM. Dependent variable: Sanctions in million USD *per participant* ($\bar{f}$). $N = 181$. $F(3, 180) = 2.83$, $Prob > F = 0.0941$, $R^2 = 0.0054$.

Table A11: Relationship between the number of cartel members and sanctions per member

	Coef.	Std. Error	t-stat.	p-value	90% Confidence Int.	
#Cartelists	0.3782	0.6045	0.63	0.532	-0.6213	1.3776
#Cartelists ²	-0.0207	0.0169	-1.22	0.223	-0.0488	0.0073
Constant	8.7137	3.0991	2.81	0.005	3.5898	13.8376

Estimation method: LPM. Dependent variable: Sanctions in million USD *per participant* ($\bar{f}$). $N = 181$. $F(2, 180) = 5.48$, $Prob > F = 0.0049$, $R^2 = 0.0101$.

Table A12: Relationship between the number of cartelists and sanctions