How a cartel operates. Evidence from Graphite Electrode Cartel from A Social Network Perspective

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Abstract

This article analyses the organization of communication in the Graphite Electrode cartel. By using European Commission data, we reconstruct the network of communication among cartel's participants. From this information, we can state that the Graphite Electrode conspiracy is organized in a decentralized way, where the hierarchical rank of participants was key in the organization of meetings. The low level of density index in the overall network may indicate that cartel's designers took care about security target by reducing the level of communication. The analysis of different centrality measures may suggest that cartel's instigators exerted a role of coordinators, but in a position such that they remained hidden from antitrust scrutiny. That is, operativeness could has been limited by the security target.

JEL Classification Numbers: L1, L4

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1. Introduction

The success of a cartel depends on the conspirator's ability to design appropriate decision making structures. As Levenstein and Suslow (2006) said "Successful cartels

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develop mechanisms for sharing information, making decisions, and manipulating incentives through self-imposed carrots and sticks". Moreover, successful cartels design organizational structures such that they be able to challenge any external threat.

This article describes the internal organization of communication among the Graphite Electrode (GE) cartel's members. Our aim is to understand the organizational economics of an enterprise that must operate and maintain its activities but in secret. To this end, we use tools from social network analysis.

Collusive cartels require extremely careful organization to succeed, and the organization is beyond fixing price. The organization of its internal communication is a device with two aims, namely an operativeness aim and a concealment aim against any external menace. Thus, the internal organization of communication involve to define the contacts, the frequency of contacts, who would be in contact with whom, and for what. All these things imply to define tasks and to define the allocation of authority of decision making among participants. Some relevant issues that collusive cartel designers should solve are: who and how decides on prices and on market allocations, who and how implements such allocations, and who and how monitors those agreements. In the *who* and *how* cartel designers have into account market conditions, and the pursuit both operativity in functioning and protective against any external disruption.

While every cartel has its owns characteristics and circumstances, the graphite electrodes cartel is an example among successful profitable cartels, of course while lasted. The U.S. Department of Justice‘s investigation when described the offence clearly stated that cartel members participated in discussions concerning: (1) the present and future prices, (2) the elimination of price discounts, (3) the allocation of volume among conspirators, (4) the division of the world market among themselves and designation the price leader in each region, (5) the reduction or elimination exports to members‘ home markets, (6) the restriction on capacity, (7) the restriction of non-conspirator companies‘ access to certain graphite electrode manufacturing technology, (8) the exchange sales and customer information in order to monitor and enforce the cartel agreement.

Meetings among cartel participants of GE cartel were the artefacts of communication to carry out tasks such as *design* of agreements, their *implementation*, and their *monitoring*. From the European Commission trial records, we have got participation or affiliation data. That is, our data consist on the description of agents who attend (or agents who are affiliated to) meetings with different aims. In this regard, we study the Graphite Electrode cartel as an affiliation network. Usually in affiliation analysing, it is assumed that attending to same meetings is either an indicator of an underlying relationship between agents (or meetings) or potential opportunity for develop one. By means of this relationship, information and knowledge can be shared among agents (or among meetings) and coordination of activities would emerge.

In the economic literature, cartels are studied as a monolithic entity. However, the design of the necessary structure to deal with the tasks required by a collusive project is crucial for its success. We might conclude that the Graphite Electrode conspiracy was organized in a decentralized way, where the hierarchical range of participants was key in the organization of meetings. The overall level of communication is measured by the density of the collusive network. We find that density index is relatively low, and this would suggest that cartel's designers take care about the security target by restricting the level of communication. From the analysis of different centrality measures, it is possible to state that cartel's instigators exerted a role of coordinators, but in a position such that they tried to remain hidden from antitrust scrutiny.

The economic and sociological literature have studied collusion from their distinct perspectives. Both have contributed to unravel price-fixing conspiracies, and help us to frame our description of the Graphite Electrode Cartel. From the economic literature, several papers from industrial organization study problems that relate to our work. In this strand, Genesove and Mullin (2001) analyze the private discussion within Sugar cartel to study the inner working of it. From this narrative evidence, they highlight the role of communication as a device for coordination. Harrington (2006) describes from European Commission decisions collusive outcomes in terms of setting prices, market allocation, monitoring agreements, punishment methods, and some operational procedures related the frequency of meetings, and some issues related to organizational structure of cartels.

Additionally, Clark and Houde (2013) by using weekly station-level price data they conduct an empirical analysis about a cartel in the Quebec's retail gasoline market. They describe the internal functioning of the cartel and the difficulties of successful colluding given the presence of asymmetric colluding firms, and highlight the strategies used to deal with that. They find that asymmetric pricing cycles, and a transfer mechanism to low-cost stations were the artifacts used to sustain a successful collusion. In this line, Wang (2008) studies how communication is used by a retail gasoline cartel in Australia to coordinate price increases. By using a data set from the trial record, Wang quantifies the pricing dynamics and the communication patterns. He shows that the collusive communication and pricing behaviour is captured by the price cycle equilibrium of the Maskin and Tirole (1988) model. Moreover, Asker (2010) studies the internal organization of a bidding cartel by analysing the conduct of a ring in the market for collectable stamps in North America that lasted for over 15 years. From a different perspective and by using social network tools, we also study the internal functioning of the cartel by analysing the path and the organization of communication among cartel's members.

From sociological literature, several articles from organization crime theory contribute to our understanding of this type of white-collar crime. In this strand, Baker and Faulkner (1993), Faulkner et al (2003) have largely study this kind of crime. Baker and Faulkner (1993), study the network of communication in conspiracies in switchgear, transformers, and turbines. They find that network structure depends on information-processing requirements imposed by product and market characteristics. They test the causal relationship between personal centrality in the network with verdict, sentence, and fine. Furthermore, Faulkner et al (2003) find that cartel continuity and the corporate authority of cartel are strong predictors of effectiveness in the conspiracy.

In the same line of the literature, Morselli et al (2007) analyse the trade-off between efficiency and security in criminal networks by comparing terrorist with criminal enterprise networks. They find that criminal enterprise networks, given their monetary ends, they are organized in a way such as efficiency is prioritized over security aim.

This article is structured as follows. In the next section we discuss about the organization of a collusive project. Section 3 presents basic concepts on affiliation networks, and Section 4 describes some salient characteristics of graphite electrode market. From a network perspective, in section 5 we study the internal organization of communication, and we analyse the organization of meetings and the level of coordinaton of activities. We conclude with some remarks in section 6.

2. A social network approach to price-fixing cartel

We assume a cartel is organized along a set of meetings (or tasks) that allow to elaborate and institutionalize cartel rules of exchange, of collective understanding regarding with who transact with whom and in which conditions. In this regard, we define a social organization structure by the triple

$$S = \{N, M, G\}$$

where

- N is a set of agents (or actors) who participate in cartel activities, and they are indexed by $i = 1, 2, ...N$. They are executives of different ranks in the hierarchy from firms participating in the collusion.
- M is a set of meetings held by cartel members, $M = \{m_1, m_2, ...\}$
- G is a network of relationships between these two sets, i.e. N and M.

Strictly speaking, G is an affiliation network in the sense that agents participate in (or are affiliated to) cartel meetings.[1] To define who goes to which meeting implies to

[1] To attend to meetings is only by invitation, so that an actor can refuse to participate in it.

set the structure of communication and coordination among meetings, among agents, and between meetings and agents. In other words, to design the affiliation network G implies to delineate a matrix of communication in the collusive cartel.

We assume that a Designer,D, will choose network $G \subseteq \mathcal{G}^{N\times M} = \{g_{ij} : i \in N \wedge j \in M\}$. On the other hand, there exists an external agent, an Antitrust Authority (AA), that investigates any particular agent i with a certain probability $\alpha_i(G)$. For simplicity, we assume that this probability is the same for all agents in the network G, $\alpha_i(G) = \alpha$.

The pay-off to the Designer from choosing $G \subseteq \mathcal{G}^{N\times M}$ when the AA has a inspection policy α arises out from the level of operational capacity, $\mathcal{OC}(G)$, and security, $\mathcal{S}(G;\alpha)$, that G allows to achieve. We assume that that pay-off is:

$$\Pi^D(G;\alpha) = \mathcal{OC}(G) \times \mathcal{S}(G;\alpha)$$

Operational capacity and security level are two complementary aims; i.e. the collusive cartel cannot achieve its goals without neither operation neither security. The operational capacity that the collusive project achieves will depend on the level of communication ($\mathcal{OC}_P(G)$), and of coordination among tasks ($\mathcal{OC}_C(G)$). Likewise, both communication and coordination imply that the collusive cartel will operate at a certain level of secrecy due to communication, $\mathcal{S}_P(G)$, and at a certain level of secrecy due to coordination, $\mathcal{S}_C(G)$.

Therefore, we can re-write the Designer's pay-off function, $\Pi^D(G;\alpha) = \mathcal{OC}(G) \times \mathcal{S}(G;\alpha)$, as

$$\Pi^D(G;\alpha) = \left[\mathcal{OC}_P(G)^\gamma \quad \mathcal{OC}_C(G)^\gamma\right]\left[\mathcal{S}_P(G;\alpha)^\beta \quad \mathcal{S}_P(G;\alpha)^\beta\right]',$$

where γ and β tell us the relative importance of these aims for D.

Before to define what we specifically understand about operational capacity and security, we need to briefly introduce some concepts and notations regarding affiliation networks.

2.A. **Affiliation networks: some concepts and notation**

In social network analysis, the term "affiliation" refers to membership or participation data. That is, data consists of a set of binary relationship between members of two distinctive sets. In terms of our case, one of these sets is the set of agents (N), and the other one is the set of meetings (M).[2] The set of actors corresponds to a set of collusive employees, and the set of events corresponds to a set of tasks or meetings. In the social

[2]The set N and the set M are two different entities called modes. For that, an affiliation network is a two-mode network.

network analysis, a common assumption is that co-memberships in events (tasks or meetings) is an indicator of an underlying relationship; and meetings (tasks) that share members is an indicators of a liaison or coordination between meetings (tasks) through agents. Let G denotes an affiliation matrix where the rows correspond to actors, and the columns are meetings (events) they attend. Thus, $G = [g_{ik}]$ describes the "affiliation" of agents to meetings, where $g_{ik} = \{0, 1\}$, and $g_{ik} = 1$ indicates that agent i attends to (is "affiliated" with) meeting k; and zero otherwise.

Furthermore, $n_k = \sum_i^N g_{ik}$ defines the number of attendees to meeting k, and $n_i = \sum_k^M g_{ik}$ indicates the number of meetings that i attends, i.e. the activity level of agent i.

We denote by X^N the matrix that indicates the number of memberships shared by each pair of agents, where $X^N = GG'$. Furthermore, let $X^M = G'G$ denotes the overlap of meetings, i.e. X^M gives the number of agents shared by each pair of meetings.

Example Consider a set of employees $N = \{1, 2, 3\}$, and a set of meetings (tasks) $M = \{A, B, C\}$. Given these two sets, a possible affiliation network G is as follows:

$$G = \begin{array}{c|ccc} & A & B & C \\ \hline 1 & 1 & 0 & 1 \\ 2 & 1 & 1 & 1 \\ 3 & 1 & 1 & 0 \end{array}$$

That is, agents 1, 2 and 3 attend to meeting A; agents 2 and 3 attend to meeting B; and agents 1 and 2 attend to meeting C. Additionally, for example, meeting A has three attendees, $n_A = 3$; and agent 1 attends to two meetings, $n_1 = 2$.

Let us note that agents are linked among them only by mean of meetings; and meetings are linked among them only by mean of agents. In other words, meetings (tasks) allow communication among agents; and agents act as coordinators among tasks (meetings). We can understand these notions by studying the following matrices.

Given the affiliation matrix G, then $X^N = GG'$, where

$$X^N = \begin{array}{c|ccc} N & 1 & 2 & 3 \\ \hline 1 & 2 & 2 & 1 \\ 2 & 2 & 3 & 2 \\ 3 & 1 & 2 & 2 \end{array}$$

In the main diagonal we have the number of meetings that each agent attends,[3] and off-diagonal we have the number of times that an agent i meets with an agent j. For

[3]This number corresponds to degree centrality of the actor.

example $x_{13}^N = 1$ means that agent 1 and agent 3 meet each other one time (in meeting A).

It is important to note $\sum_j x_{ij}^N$ tells us the total level of activity of actor i. That is, it is the number of contacts that an agent has with other actors, counting other agents each time they are encountered.

Moreover, $X^M = G^{'}G$, where

$$X^M = \begin{array}{c|ccc} M & A & B & C \\ \hline A & 3 & 2 & 2 \\ B & 2 & 2 & 1 \\ C & 2 & 1 & 2 \end{array}$$

In the main diagonal we have the number of attendees to each meeting, i.e. $x_{33}^M = 2$ means that meeting C has 2 attendees.[4] Moreover, the numbers off-diagonal are the number of agents that meeting i shares with meeting j. For example $x_{13}^M = 2$ means that meeting A and meeting C share 2 agents (in our example, agent 1 and 2) .

Again, it is worth noting that in this case $\sum_j x_{ij}^M$ tells us the level of activity that the attendees to meeting A have had.

2.B. **Operational capacity**

We assume that the operational capacity of collusive cartel is defined by the overall level of communication among agents which takes place in each meeting, likewise through the level of coordination among agents and among meetings (or tasks).

Communication level, $\mathcal{OC}_P(G)$. We consider that the level of communication in meeting j is proportional to the number of agents that participated in it. We measure the level of communication in meeting j as $\frac{\sum_{i=1}^N g_{ij}}{N}$.[5]

Therefore, by considering only the communication aim, the operational capacity of the collusive cartel can be defined by the following ratio:[6]

$$\mathcal{OC}(G) = \frac{\sum_j^M \sum_{i=1}^N g_{ij}}{M \times N}.$$

Given that $\sum_j \sum_i g_{ij} \leq (M \times N)$ for any $G \in \mathcal{G}^{N \times M}$, then $\mathcal{OC}(G) \in [0, 1]$. Thus, if $\mathcal{OC}(G) > \mathcal{OC}^{'}(G^{'})$, we can interpret that the level of operativeness in affiliation network

[4]This number corresponds to the degree centrality of the meeting.

[5]That is, $\frac{\sum_{i=1}^N g_{ij}}{N} = \frac{n_j}{N}$.

[6]We could introduce more sophisticated expression to illustrate that, for example, that such operational capacity could be natural limited by some diminishing marginal return on the number of agents. Nonetheless, our approach pretend to capture the more salient aspect of organization of communication.

G is greater than in G'.

If, in addition, agents coordinate their tasks (meetings), the overall operational capacity will be greater.

Coordination among meetings (or tasks), $\mathcal{OC}_C(G)$. Given that meetings are linked among them by mean of agents, it means that they act as coordinator between tasks. We assume that the overall level of coordination among meetings can be captured by counting the number of agents that a pair of meetings (i and j) share, x_{ij}^M, in terms of the total number of agents N. Hence, by considering only the coordination aim, the operational capacity of the collusive cartel can be defined by the following ratio:

$$\mathcal{OC}(G) = \frac{\sum_{i}^{M}}{M} \left[\sum_{j:i<j}^{M} \left(\frac{x_{ij}^M}{N} \right) \right].$$

(Since the matrix X^M is symmetric ($x_{ij}^M = x_{ji}^M$), we only consider elements at one side of diagonal in matrix X^M.)

Example. Let us consider the following affiliation matrices and their corresponding graphs:

Case I: G				Case II: G'				Case III: G''			
	A	B	C		A	B	C		A	B	C
1	1	0	0	1	1	1	0	1	1	1	1
2	0	1	0	2	0	1	1	2	1	1	1
3	0	0	1	3	1	0	1	3	1	1	1

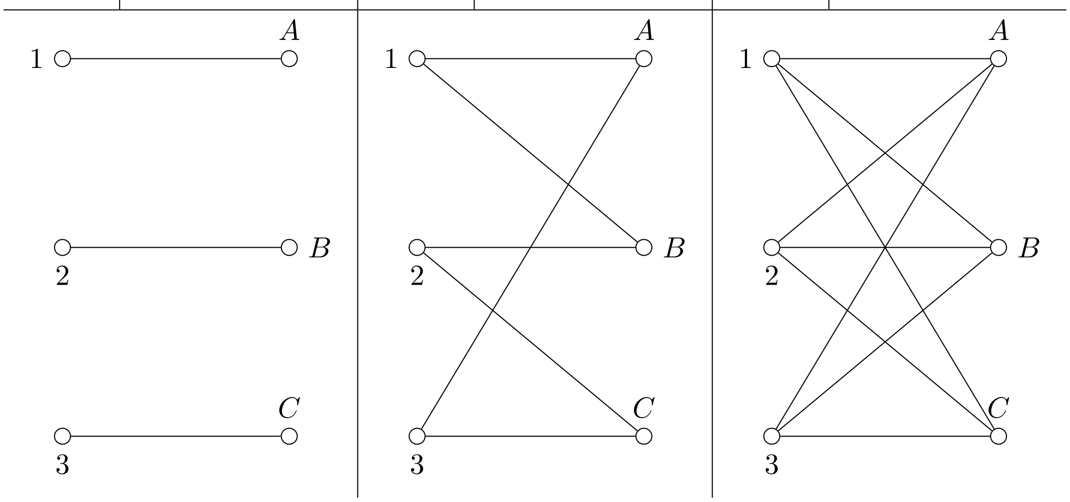


Table 1: Operational Capacity.

	Case I: G	Case II: G'	Case III: G''
Communication level	$\mathcal{OC}_P(G) = \frac{1}{3}$	$\mathcal{OC}_P(G') = \frac{2}{3}$	$\mathcal{OC}_P(G'') = 1$
Coordination level	$\mathcal{OC}_C(G) = 0$	$\mathcal{OC}_C(G') = \frac{1}{3}$	$\mathcal{OC}_C(G'') = 1$

Table 2: Operational Capacity.

In the first case, one agent is in charge of only one task, and then it is no possible the coordination among them. In the second case, each agent attends to two meetings in a way such that there always exists a different agent that coordinates two different tasks. Therefore, $\mathcal{OC}(G') > \mathcal{OC}(G)$. Finally, in the third case, the level of communication and coordination attain their maximum value. Even when we might observe some level of redundancy both in communication and coordination, we assume that such redundancy allows to achieve a greater level of operation capacity.[7]

2.C. Security: the level of secrecy

We assume that with a certain probability α, an agent i is investigated, and thus he exposes a fraction of the network, $(1 - \epsilon_i(G))$. In other words, $\epsilon_i(G)$ is the expected fraction of the network G that remains in secrecy in case agent i is investigated by AA. Then, given the network G chosen by D, the overall level of secrecy or security that G achieves is defined as $\mathcal{S}(G) = \alpha \sum_i^N \epsilon_i(G)$.

Security due to participation in meetings, $\mathcal{S}_P(G)$. We assume that the fraction of network G that is exposed when i is investigated depends on the number of agents that i has came across in meetings where he attended. Thus, the proportion of agents that i comes across in meeting j is $\frac{(\sum_i g_{ij} - 1)}{(N-1)}$. By summing this number over all meetings that i has attended, we obtain $(1 - \epsilon_i) = \frac{\sum_{j:g_{ij}=1}}{M} \left(\frac{(\sum_i g_{ij} - 1)}{(N-1)} \right)$. Therefore, the level of security that G achieves, by only considering the participation of agents in meetings, is

$$\mathcal{S}(G) = \alpha \sum_i^N \left(1 - \frac{\sum_{j:g_{ij}=1}}{M} \left(\frac{\sum_i g_{ij} - 1}{N - 1} \right) \right).$$

Security due to coordination between meetings, $\mathcal{S}_C(G)$. Let's recall that x_{ij}^M is the number of agents in common between meetings i and j; i.e., the number of agents that are involved in the coordination of tasks i and j. Thus, if any of those agents would be investigated, the fraction of the network that remains unexposed is $(1 - \frac{x_{ij}^M}{N})$. Therefore,

[7] We can think that redundancy is good in the sense that everybody is aware about all cartel activities and that avoid miss-coordination problems, etc etc.

by solely considering this factor, $\mathcal{S}(G)$ is

$$\mathcal{S}(G) = \alpha \sum_{j:i<j} \left(1 - \frac{x_{ij}^M}{N}\right)$$

Example. Let us consider for the aforementioned affiliation matrices:

	Case I: G	Case II: G'	Case III: G''
Security due participation	$\mathcal{S}_P(G) = 3\alpha$	$\mathcal{S}_P(G') = 2\alpha$	$\mathcal{S}_P(G'') = 0$
Security due coordination	$\mathcal{S}_C(G) = 3\alpha$	$\mathcal{S}_C(G') = 2\alpha$	$\mathcal{S}_C(G'') = 0$

Table 3: Security level.

!!!OJO dan igual por los números...!!!!

From the above examples we are able to understand the trade-off between operational and security aims to collusive Designer.

Example. Given the above affiliation matrices, we can compute Π^D for $\gamma = \beta = 1$.

	$\mathcal{OC}_P$	$\mathcal{S}_P$	$\mathcal{OC}_C$	$\mathcal{S}_C$	Π^D
Case I	$\frac{1}{3}$	3α	0	3α	α
Case II	$\frac{2}{3}$	2α	$\frac{1}{3}$	2α	2α
Case III	1	0	1	0	0

From the example, let us note the following. First, operability and security go in opposite direction; second, intermediate levels of communication and coordination are better than other situations; third, since full communication and coordination completely expose the network to AA, then this is the worst choice for D.

3. Graphite Electrode Cartel

In this section, we will briefly describe the Graphite Electrode Cartel. The cartel investigation began after a customer complaint, and its activities took place around the world (U.S, Europe, Australia and Asia) between about 1992 to 1998. As a result of collusive agreements the prices rose around 45% in average around the world. In this part, we describe the market for the Graphite Electrode, and some characteristics of the production process. Thereby, we pretend to gain understanding about the communication process that was needed to hold the collusive agreement in this market.

Graphite electrodes (GE) are large carbon columns used by electric arc furnaces (EAF) or "minimills" in the making of steel. These mini-mills use graphite electrodes to generate the heat necessary to melt scrap metal and convert it back into a marketable steel product. Electrodes can be up to 700 mm in diameter and 2,800 in length and weigh up to 2,200 kg. They form part of the roof structure of the furnace. After the furnace is filled with selected scrap, the electrodes are lowered until the tips almost touch the scrap. Electricity is passed into the electrodes, and by this means to the scrap. As conductors of electricity, graphite electrodes generate the necessary heat (up to 3,000^{o}C) to melt scrap steel. It is necessary nine electrodes, joined in columns of three, which are consumed in approximately every eight hours.

There are no product substitutes for graphite electrodes, other than traditional methods of making steel (oxygen or open hearth process). However, GEs make up only 6-7 percent of the cost of production in minimills. So that, if the price of GEs were to rise, minimills would be able to absorb such price increase before being obligated to shut down.

The major producers of GE are multinational firms. The market is characterized by an oligopolistic structure with high entry barriers.

In this article, we are concentrated in the European market where 280,000 tones of GE were produced. In the world market, the largest produced of GE is UCAR, the second largest one is SGL Carbon, both producing in Europe and North America. The third producer is Showa Denko and its production is concentrated in Japan and United States. However, firms have a direct sales force that handle domestic and worldwide sales, as well as independent sales agents. Other firms that supply the European market are VAW, Conradty, C/G, some Japanese producers (about 3-4% of the European market by conspiracy dates) and Indian, Chinese and Russian producers supply the rest of the demand in this market.

The conspiracy The conspiracy took place between 1992 and 1998 approximately. The firms involved in the collusive agreements were SGL Carbon AG (SGL), UCAR International Inc (UCAR), VAW Aluminum AG (VAW), Showa Denko K.K.(SDK), Tokai Carbon Co. Ltd.(Tokai), Nippon Carbon Co. Ltd (Nipon), SEC Corporation (SEC), and The Carbide Grapite Group Inc. (C/G).

Cartel members carried out practices contrary to competition law. These practises consisted on: 1) fix the prices of the product; 2) agree on and implement a mechanism for implementing price increases; 3) allocate markets and market share quotas; 4) agree not to increase production capacity; and 5) agree not to transfer technology outside cartel members.

The machinery to define, to implement and to monitor their agreements was organized by meetings of several different levels: periodic “Top Guy” meetings, regular “Working Level” meetings, national and regional meetings, and bilateral contacts between firms. In this article, we concentrate on Top Guy, and Working Level meetings and some bilateral contacts in the European market.

Data and research design The principal data source is the information publicly accessible by the European Commission.[8] It includes 244 paragraphs with information about cartel operation and description. We use that to create a matrix of communication. We would emphasize that given the confidentiality of this data, it was very difficult to reconstruct the exact network of communication. Nonetheless, in the Appendix we clarify the exact piece of information in which we base to construct each tie.

The final network is composed by 21 individuals and 33 meetings. We do not include national or binational meetings.

After matrix was created, all participant are distinguish by rank, and meetings are distinguished by their subject. That is, actors are labeled by the name of firm from which they belong, and by the hierarchical rank that they hold there. We consider three levels of hierarchical ranks. CEOs are considered to be of rank 1, where 1 is the highest rank. General managers were labeled as rank 2. Sales managers were coded as rank 3.

Regarding meetings, we consider four types of meetings. Meetings of type S are meetings whose aim were to maintain the discipline among members. Among such kind of meeting, we also include the seminal meeting where main participants agreed the overall scheme by which the world market would be cartellised. The second type of meeting are implementation ones (I); that is meetings where different tasks regarding price set and market allocation are defined. Meetings of type M are monitorig ones; that is meetings where members share information about prices, allocation quotas and so on. Finally, we consider bilateral meetings, labeled by B, which are meetings held by two agents of two different conspirators. In this case, we distinguish bilateral meetings whose goal is to discipline members (SB), bilateral meetings for implementation purpose (IB), and bilateral meetings for monitoring purpose (MB).

In order to identified each meeting, they have been labelled chronologically (1,2,3,...), and each kind of the meetings is graphically identified by the shape of the node.

UCINET software (Borgatti et al., 2002) was used for running the analysis.

Basic statistic of cartel's organization are summarizing in the following table.

[8] http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=1_36490

Type of meeting	**# of meetings**	**# of attendances**	**Average of rank**
S	5	27	1
I	4	25	2,25
I/M	1	2	3
M	14	115	2,74
Subtotal	24	169	
Bilateral meetings			
SB	1	2	1
IB	3	6	1,67
IB/MB	2	4	1
MB	3	6	1,33
Subtotal Bilateral	9	18	
Total	**33**	**187**	

Table 4: Descriptive statistics

The internal organizational of the GE cartel. A social network perspective. In this part, our main purpose is to get a first understanding about the organization of communication among cartel's members. Thus, we study the pattern and the level of communication among agents, and the coordination among tasks or meetings.

The figure 2 plots in the same graph both meetings and agents. Agents are represented by red circles, and meetings by squares of different colors depending on the type of meeting. A line between a red circle (an agent) and a square (a meeting) represents a tie between these two nodes (meeting and agent). That is, a line between an actor and a meeting means that this actor has attended to that meeting. In this layout, the distances between two nodes are meaningful in the sense that two nodes are close to the extent that the distance between them is short. That is, in the following graph two agents are near each other if they attended the same meetings (i.e. both actors are assigned to the same tasks), and two meetings are near each other if they are attended by the same agents (i.e., two tasks are near if they are assigned to same actors).

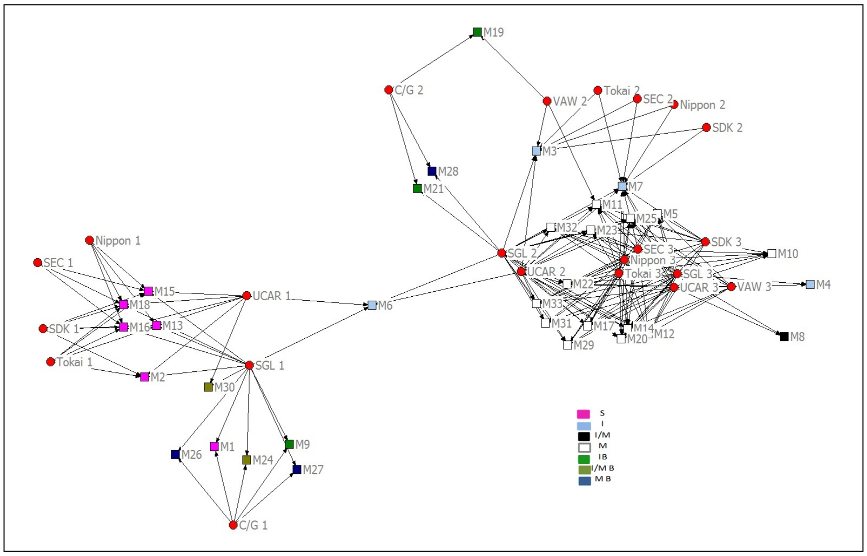


Figure 1: Agents and Meetings

This representation makes clear that the rank of actors is key in the configuration of meetings. At a first glance, we are able to distinguish that agents UCAR1 and SGL1 are connected with other rank 1's actors by meetings of type S (pink squares). Furthermore, agents UCAR2 and SGL2 are connected with agents of rank 2 and 3 by implementation and monitoring meetings (white and light blue squares).

Meetings of type M (monitoring meetings) were mainly attended by members of rank 3 (sales managers). On the other hand, meetings of type I (implementation meetings) were mainly attended by members of rank 2 and rank 3 (general and sales managers). It worth noting that meeting M6, an implementation one, is the connection between rank 1's employees and the other group of agents.

Firm C/G participated in the cartel in a marginal role, i.e., only C/G1 and C/G2 attended to meetings, they were bilateral contacts with UCAR and SGL's agents. Moreover actors VAW1 and C/G3 are included because of we consider that some tasks could not have been done without them, however it is hard to know to which meeting they have attended, if any.

In sum, we observe a pattern of attendance; namely, agents of rank 1 have attended to meetings of type S; implementation meetings were mainly attended by members of rank 2; and sale managers have participated in monitoring tasks. This observation is also confirmed by analysing the average rank of agents who attended to each type of meeting (see Table 2).

Type of meeting	**Average of rank**
S	1
I	2,25
M	2,74

Table 5: Rank by meeting

Observation 1 In the Graphite Electrode cartel the rank of actors is key in the configuration of meetings: less knowledgeable agents dealed with routine activities, and more expert actors specialized on giving directions and solving harder tasks.

As a final remark, we highlight that agents from firms UCAR and SGL have acted as a kind of bridge among conspirators. Likewise, middle managers from UCAR and SGL have a lot of contacts both with members of their rank and with members of other ranks by mean of implementation and monitoring meetings.

Now, we try to get a deeper understanding about how cartel organization has dealt with the trade-off between the operational capacity and security aims.

4. The trade-off between operatibility and security through density measures in GE Cartel

The overall level of communication. To measure the current level of communication we calculate the density of relationships. This number can be interpreted as the level of communication that arises after take into account both operativeness and security goals. The density is an index that measures the degree of connection in a population. The density is calculated as the number of actual ties divided by number of all possible ties, i.e, $N \times M$, where N is the number of rows (agents) and M is the number of columns (meetings) in our matrix of relationships. As agents attend to more meetings, the density index increases. Thus, as density index is larger, more information can flow between agents through meetings. Nonetheless, at the same time, as agents attend to more meetings, it becomes easier to discover these illegal activities as agents become more visible.

The density score for the Graphite‘s cartel is $0,236$ which means that of all possible ties among agents and meetings ($n \times m = 24 \times 33$), 23,6% are actually present.

Covert networks are said to be sparse or to have low density.[9] Morselli et al (2007) suggest that density is related to the type of covert activity, where terrorist networks are denser than criminal ones. Furthermore, Hefstein and Wright (2011) argue that pre-existing relationship among members or specific attributes could explain variation in the density score among networks. Baker and Faulkner (1993) found that the density of three communication networks in the heavy electrical equipment industry were around 23.3%, 32.4%, and 35.5%.

So that, in spite of there have no common cut point as to define what it is high or low density, we can say that the graphite network is not so dense as it would be if all possible ties were formed, but it is at least so dense than other cartel cases.[10]

Observation 2 Following the density score, the overall level of communication in Graphite Electrode cartel was at least as other cartel's cases, and maybe not so high as the maximum

[9]Demiroz et al compute a density of 9.8% for a terrorist network; Calderoni (2012) gets a density around 12% in the ‘Ndrangheta and cocaine drug network.

[10]Baker and Faulkner (1993).

level of commumication.

Now we explore deeper in the coordination of activities and the communication among agents.

Coordination among activities. In order to study the coordination among activities (i.e., the relationship among meetings), we concentrate about the pattern of ties that arises out of the co-attended matrix X^M.[11] By using the Graphite Electrode data we obtain a matrix X^M in which entries show how many agents attended both meeting in common. In the main diagonal of X^M, an entry a_{ii} accounts for the number of agents that participated in meeting i and, off-diagonal, an entry a_{ij} tells us the number of employees that meeting i shares with meeting j (see Example in Section 3). Thus, a_{ij} would measure the level of coordination that meetings i and j had have, in the sense that the number of agents in common (a_{ij}) would allow that information flows from meeting i to meeting j.

The following graph represents the matrix X^M, and it shows the similarities among meetings, i.e. each meeting is a node that appear close to each other to the extent that these meetings share many agents.[12] In the graph, line thickness corresponds to tie strength, i.e. number of actors shared between meetings involved in the extremes of a line.

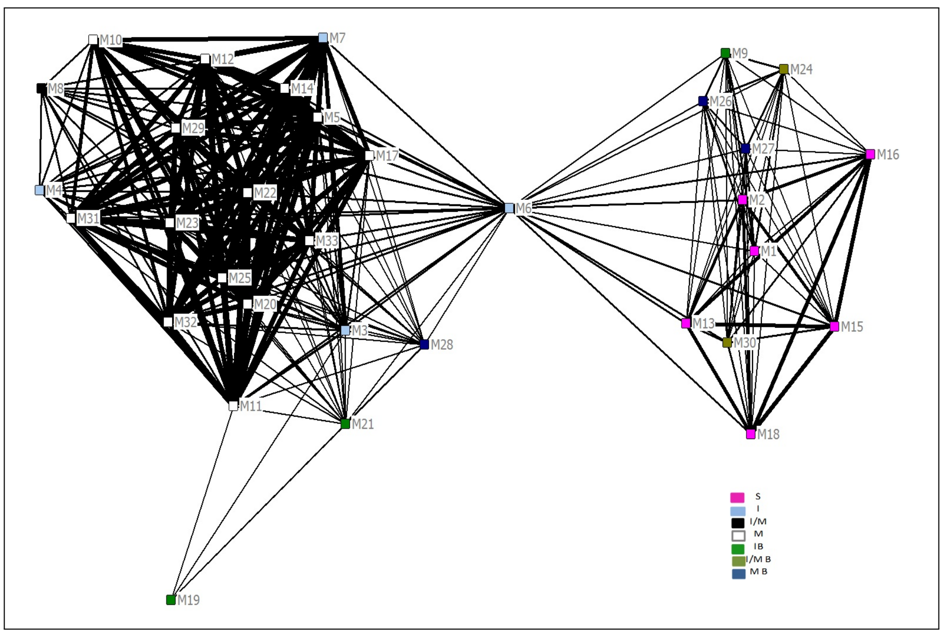


Figure 2: Co-affiliation relationships: meetings

The diagram shows the bridging role of meeting M6, an implementation one. This meeting is co-attended by employees that also participated in seminal and monitoring meetings. Meetings in a role such as M6 could be regarded as key in the extent to which information is

[11]See Section 2.

[12]It is important to note that two meetings could be similar (i.e., co-attended) just because they are well attended. Therefore, we use the Bonacich's (1972) normalization that measures co-attended relative to the size of the meetings.

able to flow from one kind of meeting to another one. In a sense, it could said the same for the meetings M3 and M7.

Additionally, let us observe that monitoring (white squares) and type S meetings (pink squares) are homogeneous in the sense they are co-attended by approximately the same agents within each type of events (they are close to each other within their types). If the co-attended to meetings allows the information flows among them, we may say that cartel tasks were highly coordinated.

Density among meetings. Members of a cartel need to meet to reach agreements, and to put these agreements in actions. The co-attendance to meetings might impact on the success of agreements that they have reached. Joint attendance might have positive impact on the organization of communication as it would allow a better coordination among tasks by mean of communication of agents that co-attend to meetings.

We study the general level of coordination among tasks by analysing the density index of X^M. Density between meetings measures the degree of co-attendance and connection among them. This index is measured as the number of pairs in common in terms of all possible ties. The value of the density among meetings is the average number of agents who belong to each pair of meetings. The density index for Graphite's cartel is 2.04, i.e., in average, a pair of meetings have had 2.04 agents in common.

Furthermore, we can partition the set of meetings into the five type of meetings, and we analyze the density within and between groups as a more precise measure of coordination between tasks.

	S	I	M	IB	MB
S	3.60	0.37	0.00	0.83	0.78
I	0.37	1.60	3.07	0.32	0.33
M	0.00	3.07	7.52	0.20	0.31
IB	0.83	0.32	0.20	0.5	0.87
MB	0.78	0.33	0.31	0.87	0.67

Table 6: Density among Meetings by type

In the main diagonal, we have the number of agents in common by a pair of meetings of the same type. For example, type S meetings shared, in average, 3.60 actors. In the case of implementation meetings, this index is of 1.6 actors in common by each pair of meetings; in turn meetings of type M had in average 7.52 agents in common.

Furthermore, off-diagonal values measure the number of agents that different kinds of meetings share between them. These values allow us to study the coordination between tasks because agents, that meetings have in common, facilitate coordination given the information that they allow to flow between meetings co-attended. There are a high level of coordination among implementation and monitoring tasks since meeting I and meetings M have in average 3.07 agents in common. Moreover, actors who have attended to S meetings also attended to other kind of meetings, but in this case they were some implementation or bilateral encounters. Actors who have attended to S meetings never attended to M ones, and vice versa.

Finally, although tasks S and M apparently was not coordinated, implementation meetings may have acted as the liaison between them.

Observation 3 Monitoring meetings had have a high level of coordination within their respective type. Additionally, implementation meetings may have acted as the liaison between tasks S and M.

5. The trade-off between operational capacity and security through centrality measures in GE Cartel

The precedent analysis characterize the general pattern of communication and coordination among cartel's tasks. Now, we concentrate at agent level, and we study who has been the more active agents, who has been the agents with greater level of communication, and who has been the agents that have facilitated the coordination among activities. Furthermore we analyse how, in some cases, communication has taken place but in a secrecy way. To do that, we provide a family of measures of centrality based on agent position on the Graphite Electrode's social network. The Appendix contains the scores for each node for each centrality measure.

The three measures of centrality with which we work on are degree centrality, betweenness centrality, and eigenvector centrality.

Degree centralities. The degree centrality of an agent is proportional to the number of events to which an agent has attended.[13] This measure gives an idea about the level of activity of an actor. An agent with high degree centrality is an active node with a potential greater access of information since he attends to a high number of meetings. As the level of activity increases, however, an agent will be in a more visible position faced to antitrust scrutiny.

In the Graphite cartel, agents that have more degree centrality are SGL2, SGL3 and UCAR3 in this decreasing order for degree centrality score.

Betweenness centrality. Betweenness centrality focuses on the extent to which actors sit on paths between other pairs of nodes. That is, betweenness centrality measures the ability of a node to control flows of information. Consequently, betweenness centrality captures which nodes act in a role of coordinators and gatekeepers of information. In calculating the betweenness centrality of an actor i, we focus on the collection of meetings that agent i participates. Agent i is on a geodesic between all pairs of meetings that he attends. If a given pair of meetings m_k and m_j only share agent i in common ($x_{kj}^M = 1$) then, agent i is on the only geodesic between them, and i's betweenness centrality is incremented by 1. When

[13] This measure is normalized by the maximum value possible in a given graph so that it allows to make comparisons.

meetings m_k and m_j share x_{kj}^M agents then i's betweenness centrality is incremented by $\frac{1}{x_{kj}^M}$ for each pair of meetings (m_k, m_j) that i attends.

In the Graphite cartel, actors with highest betweenness centrality are SGL2, SGL1, UCAR 2, and UCAR1 in this decreasing order for the centrality score.

Eigenvector centrality. We concentrate now on the centrality of actors by considering that an actor is central on the extend that they have ties to other actors that are themselves central. In the affiliation context, the eigenvector centrality of an actor is proportional to the centrality of meetings to which the actor attends.[14] This measure explicitly incorporates the duality between actor and meeting centralities.

In that sense, we interpret that eigenvector centrality summarizes the idea of a covert position. We assume that an agent will be detected if he is inspected, or if it is inspected any participant to meetings to which he is affiliated. Therefore, an agent will be detected due to his operational profile, i.e. due to his volume of activity, which can be measured as the number of contacts that an agent has, counting other actors each time they come across. Thus, the probability an agent i be detected is

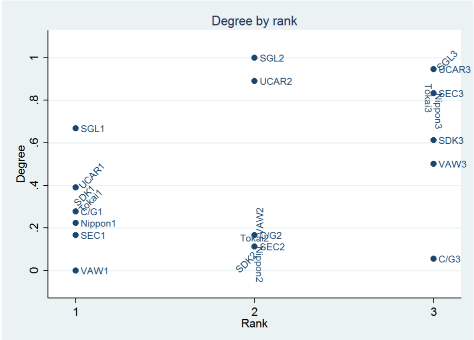
$$Pr(Detected \quad i) = \left[1 - (1-\alpha) \prod_{j:g_{ij}=1} (1-\alpha)^{n_j - 1} \right].$$

Accordingly, as a meeting becomes more popular, i.e. greater n_j, the volume of activity of each agent affiliated to it will be greater, and this will increase the visibility of agents faced to AA scrutiny.

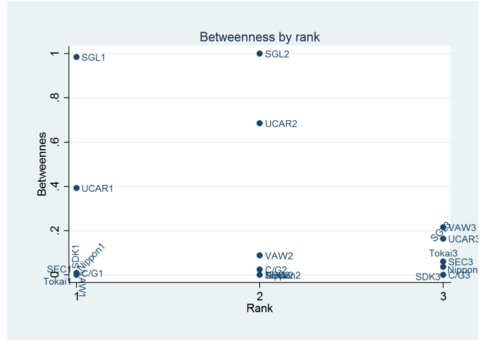
In our data, actors SGL3 and UCAR3 have the highest score in eigenvector centrality; and on the other extreme, SGL1 and UCAR1 have one of the lowest scores according to this measure of centrality.

Operativeness and Security. Discussion. As a first approach to data, the following figures depict the relationship between hierarchical rank and degree, betweenness, and eigenvector centrality. To allow us to make easy comparison across measures, we have rescaled all centrality scores so that each one ranges between 0 to 1 by dividing by their corresponding maximum values.

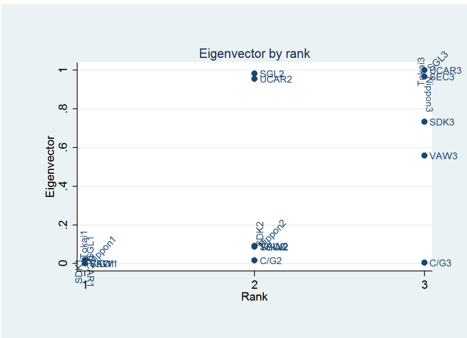
[14] Additionally, the centrality of a meeting is proportional to centrality of members affiliated to it.



(a) Degree centrality by rank



(b) Betweenness centrality by rank



(c) Eigenvector centrality by rank

Figure 3: Centrality measures by rank

Panel a) shows that agents of rank 3 display higher degree centrality than other ranks. Additionally, it is clear that, relative to their own ranks, agents from UCAR and SGL are the more active ones.

Betweenness centrality provides a good notion about who has a better control over all activities, since it measures the extend to which a node is on the shortest paths between other pairs of nodes. This position allows a node to have a strategic brokering power. Figure in panel b) shows that agents of rank 1 and 2 from UCAR and SGL have greater betweenness centrality scores than the other agents. Thus, these actors appear to have a brokerage roles for control and for the exchange of information.

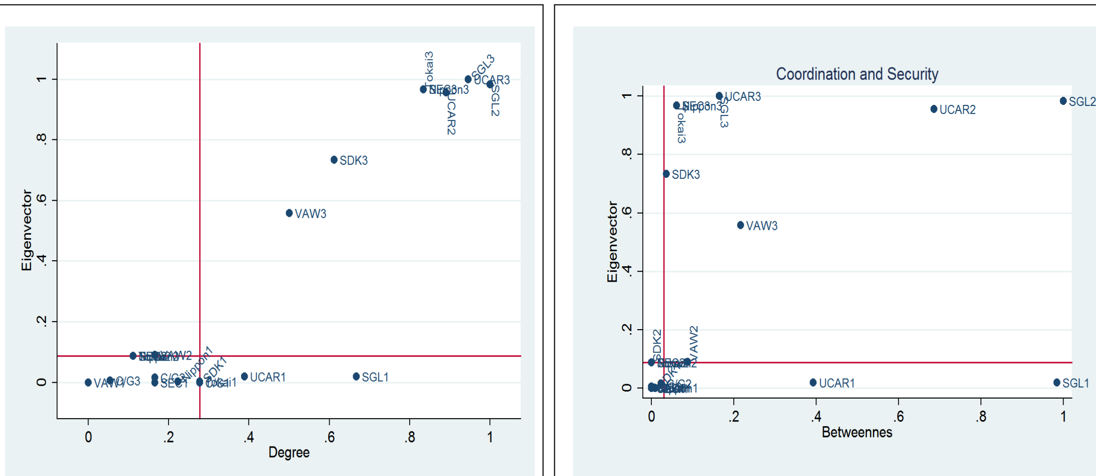
In some sense, more active nodes are in a more vulnerable position than less active ones because this fact implies a greater level of exposition and visibility faced to AA. A more strategic position is one such that allows undertake the tasks assigned and, at the same time, it provides protection in case of an investigation. Eigenvector centrality captures this notion since the level of activity is greater not only if an actor attends to more meeting but also if he/she attends to more central meetings where the flow of information might be greater. Panel c) shows that agents of rank 3 have a higher eigenvector centrality since they were more active in more central or popular meetings.[15]

[15] The degree centrality of a meeting is measured by the number of agents that attend to it.

Covert coordinators. Operativeness versus Security. If operativeness goal claims for more communication, and security goal calls for less communication, then the result of the trade-off between operativity and security could be followed by Figure 3.

Lines in the pictures show the median of the respective centrality measure. As can follow from the figure even if SGL1 and UCAR1 have a level of activity greater than the median, they did not attend to central (or crowded) meetings. The last observation can be followed by their respective low eigenvector centrality scores. Nonetheless, they have acted in a strategic position as brokers as it is revealed by their betweenness centrality scores. Therefore SGL1 and UCAR1, as leaders of the cartel, have acted as coordinators but in a covert position according the comparison between their respective betweenness and eigenvector scores.

On the other hand, agents such as SGL2 and UCAR2 have had a lot of activity, which can be followed by their degree and eigenvector scores, but they also have acted in a broker position (high betweenness centrality).



(a) Degree vs. Eigenvector

(b) Betweenness vs. Eigenvector

Figure 4: Operation vs. Security

Observation 4 Agents from firms cartel's leaders, such as SGL1 and UCAR1 have acted as coordinators (high betweenness centrality) but in a covert position (low eigenvector centrality).

6. Concluding Remarks

In this article, we reconstruct and analyse the Graphite Electrode cartel from a perspective that combines some elements from economic theory and tools from social network analysis. By doing that, we try to open the "black box" of a conspiracy, recognizing that a cartel is not a monolithic entity. We study the internal organization of communication among participants of the conspiracy. From the analysis, we find that the Graphite Electrode conspiracy was organized in a decentralized way, where the hierarchical range of participants was key in the organization of meetings.

Moreover, the overall level of communication measured by the density index is low, and it would seem to show that cartel's designers took care about security aspects of the organization by reducing the level of communication among cartel's members. We also find that monitoring tasks were highly coordinated, and implementation meetings may have acted as the liaison between the other kinds of tasks.

From the analysis of different centrality measures, we can say that cartel's instigators exerted a role of coordinators, but in a position such that they tried to remain hidden from antitrust scrutiny. That is, coordination as a proxies of operativeness could has been limited by the security target.

Our analysis is a first step in the understanding how a cartel operates from a social network perspective, and it is the first part of a bigger project where we pretend to model, from an economic theoretical perspective, the internal organizational of covert activities, either criminal or just secret activities by using tools from social network theory.

7. Appendix

Appendix 1. Data from European Commission

Appendix 2. Affiliation data

Appendix 3. Centrality measures

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