Networks and Coordination

Part I out of II

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Outline

Outline

Network Theories across the Various Weeks of SMM638

Network theory	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**
Value creation		•						
Coordination			•	•				
Network change						•	•	•
Contagion						•		•

The Leading Question

When do networks create value?

Groups of Network Theories

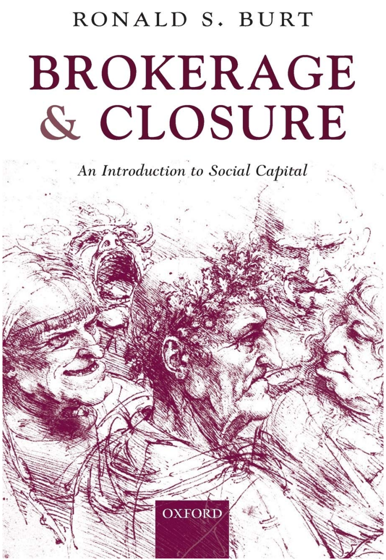
Underlying model	**Social capital**	**Social homogeneity**
Network flow	Capitalization (value creation)	Contagion
Network architecture	Coordination	Adaptation (network change)

Source is [3, page 47]

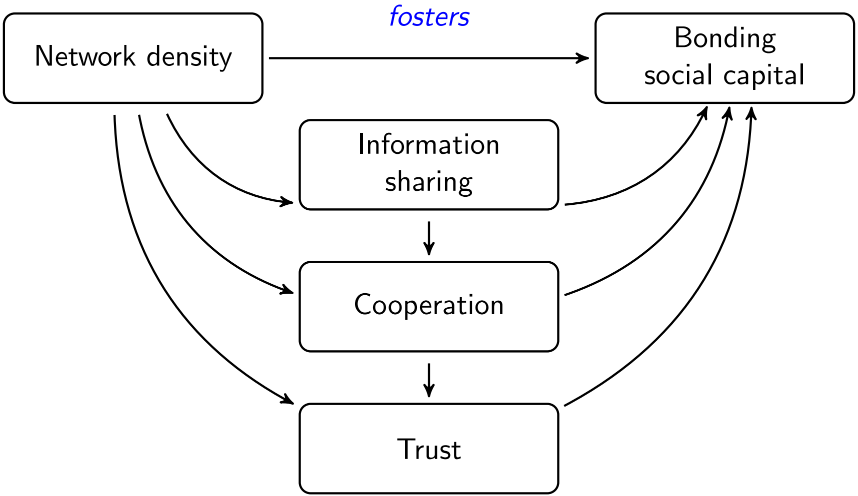
Theories on Networks and Value Creation

Mainly, the various theories on the influence of networks on value creation can be grouped into two categories:

- **Bridging** social capital theories, whose key tenet is that sparse networks bring value to individuals and groups by facilitating fresh courses of action and new ideas — a process called **network brokerage**
- **Bonding** social capital theories, whose key tenet is that dense networks bring value to individuals and groups by fostering cooperation and trust — a process called **network closure**



What Is the Outcome of Dense Networks?



Density Metrics

!! Pay attention !!

There is no single metric capturing the concept of network density

In practice, we use complementary metrics such as

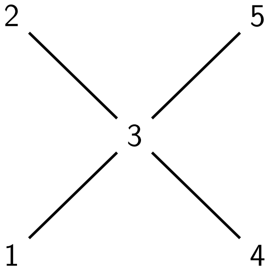
- Average degree
- Degree distribution
- Connectdeness
- Clustering coefficient

Average Degree

'Average Degree' is the mean number of connections per node in a network

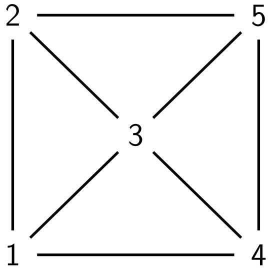
$$\langle k \rangle = \frac{1}{N} \sum_{i=1}^{N} k_i$$

A — a 'star'



$\langle k \rangle = \frac{4}{5}$

B — a 'dense' network



$\langle k \rangle = \frac{16}{5}$

Degree Distribution

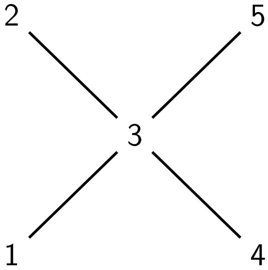
'Degree Distribution' is the distribution of the nodes across unique degree levels. Oftentimes, it is calculated to provide the probability that a randomly selected node in the network has degree k

$$\sum_{k=1}^{\infty} p_k = 1$$

hence

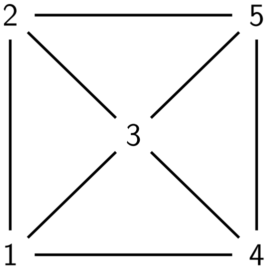
$$p_k = \frac{N_k}{N}$$

A — a 'star'



k	$Pr(k)$
1	0.8
4	0.2

B — a 'dense' network

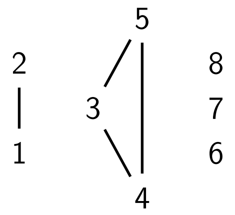


k	$Pr(k)$
3	0.8
4	0.2

Connectedeness

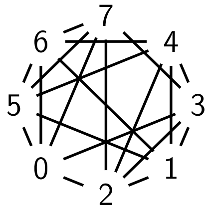
In an undirected network nodes i and j are connected if there is a path between them. They are disconnected if such a path does not exist, in which case we have $d_{ij} = \infty$

A — a disconnected network



The graph has two connected components (1-2 and 4-5-6), but it lacks overall connectivity. For example, there is not path between nodes 1 and 6.

B — a connected network



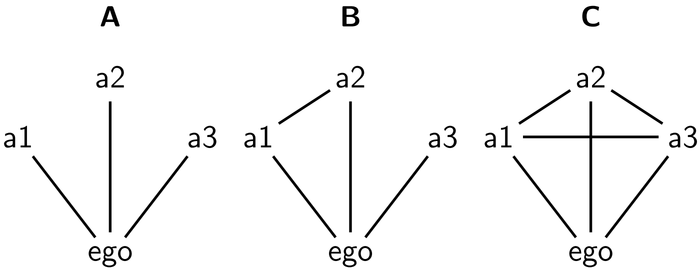
This graph is connected. Although some nodes are not directly connected (e.g., 4-7), an indirect path exists between them (e.g., 4-6-7).

Clustering Coefficient

The clustering coefficient captures the degree to which the neighbors of a given node link to each other. For a node i with degree k_i the local clustering coefficient is defined as

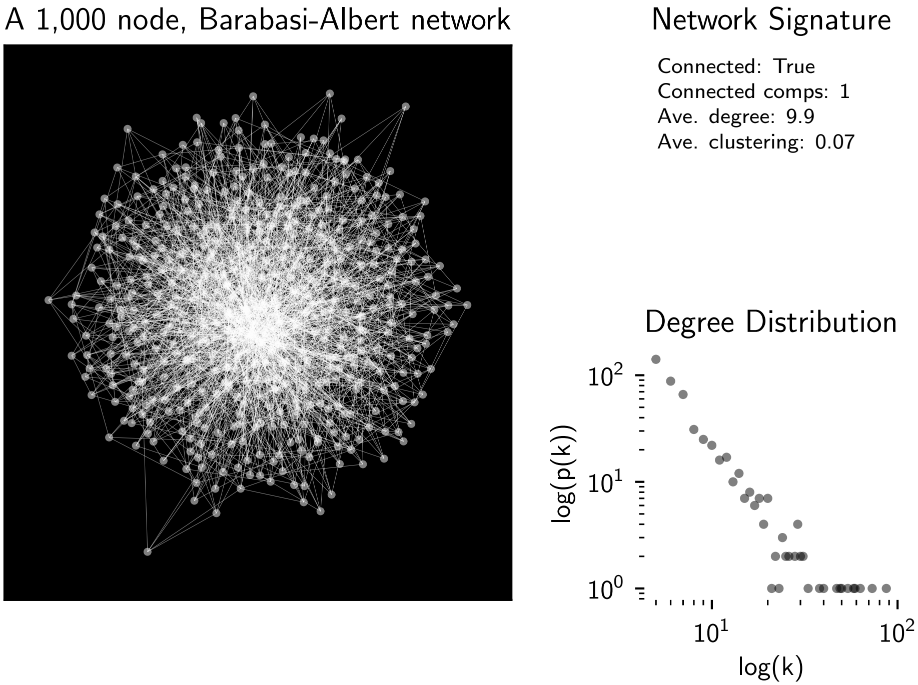
$$C_i = \frac{2L_i}{k_i(k_i - 1)}$$

where L_i represents the number of links between the k_i neighbors of node i



$C_{ego} = \frac{0}{3}$ $C_{ego} = \frac{1}{3}$ $C_{ego} = \frac{3}{3}$

Time for Python Lab!


A 1,000 node, Barabasi-Albert network
Network Signature
Connected: True
Connected comps: 1
Ave. degree: 9.9
Ave. clustering: 0.07
Degree Distribution
log(p(k))
log(k)
10^0
10^1
10^2

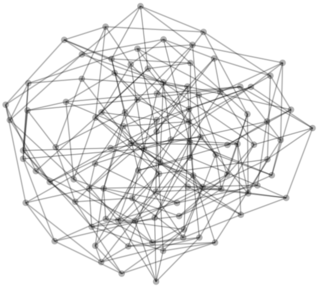
What are Small World Networks?

∼ Definition 2 — Small-world network ∼

The tendency of a network to present small cohesive groups of nodes tied together by few bridging ties.

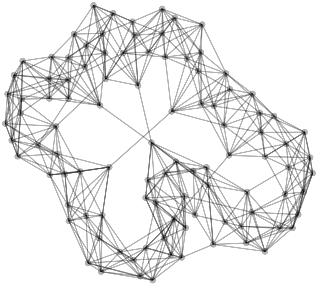
Two Alternative Network Forms

A homogenous network



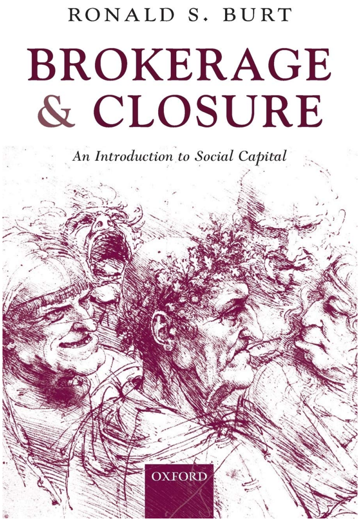
A random network with $N = 100$ nodes and $\langle k \rangle = 5$. Source [4]

A small-world network



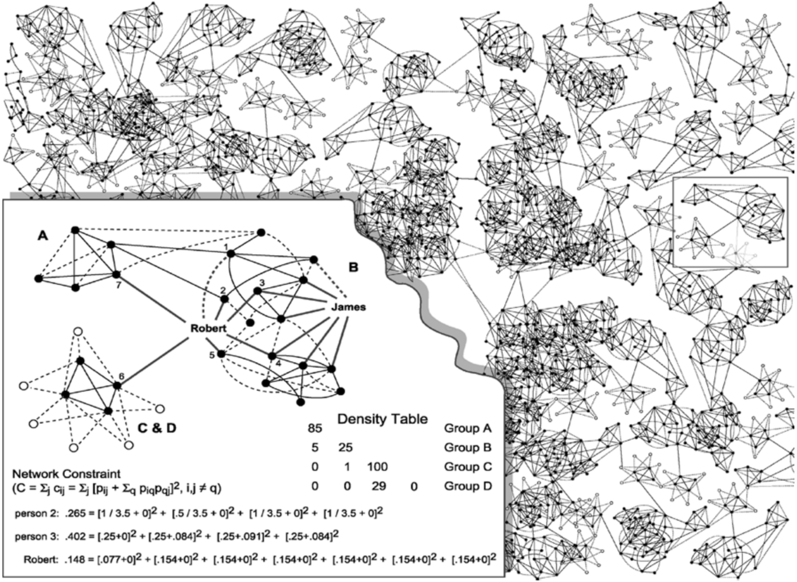
A Watts-Strogatz network with $N = 100$ nodes, 10 neighbors a node, and tie rewiring prob. 0.02. Source [5]

What is the Outcome of Small World Networks?

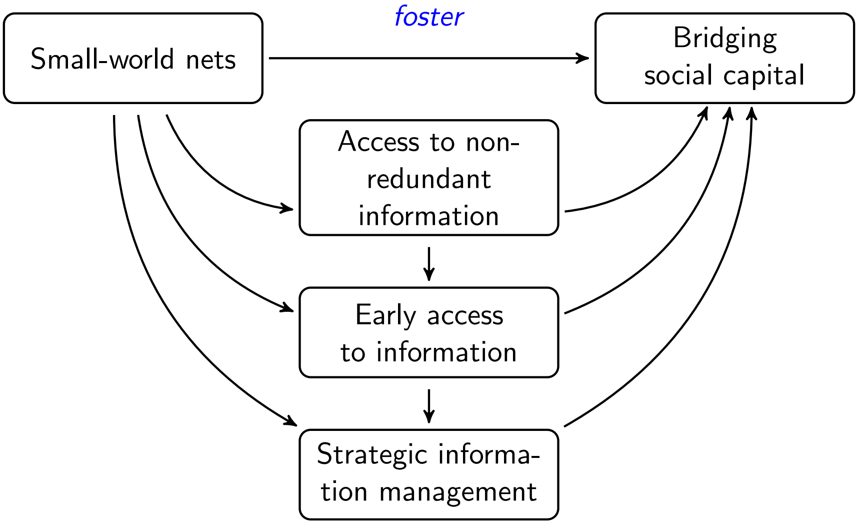


What is the Outcome of Small World Networks?

Source [2] — Fig. 1.1: The small world of organizations and markets

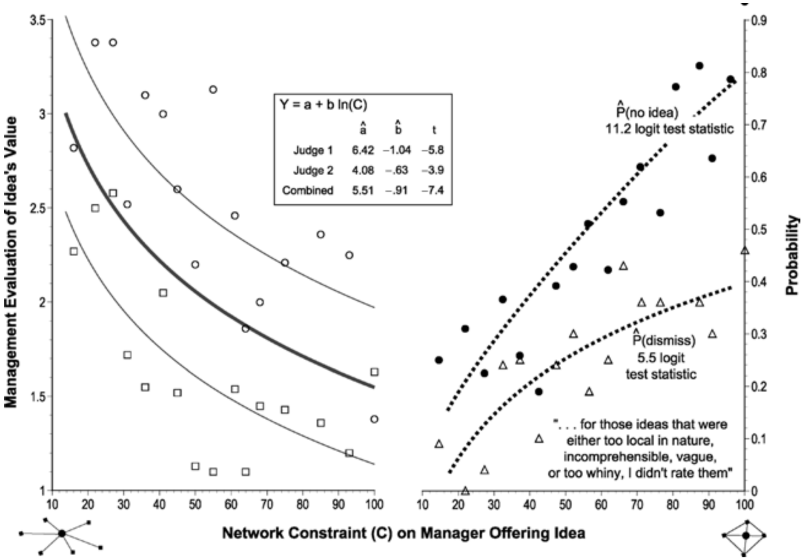


What Is the Outcome of Small-World Networks?



Evidence on the Returns of Bridging Social Capital

Source [2] — Fig. 2.1: Good ideas and brokerage



Metrics Associated with the Brokerage Process

Bridging Ties

- Edge betweenness

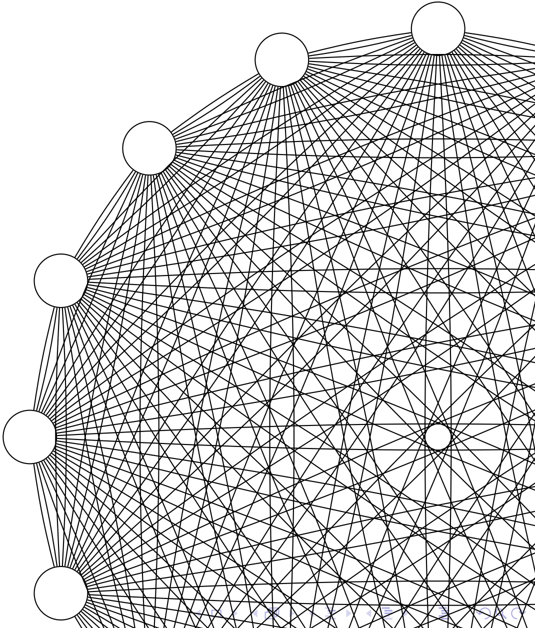
Bridging Positions

- Node betweenness
- Burt's Constraint Index

Outline

Today's Class Focus

The attention revolves around roles and positions in networks and their importance for the functioning of organizations and markets.



Groups of Network Theories

Underlying model	Social capital	Social homogeneity
Network flow	Capitalization (value creation)	Contagion
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Networks as Social Capital: Capitalization and Coordination

How do the capitalization and coordination perspectives differ?

	Capitalization	**Coordination**
Level of analysis	Individual nodes/groups of nodes — aka, the trees in the forest	The network as a whole — aka, the forest
Key tenet	(Information exchange) Networks bring resources to individual nodes	The organization and functioning of organizations/markets depend on the characteristics of its underlying (information exchange) network
Sample problem	What is the best network position for a node or a group of nodes with a given objective function (e.g., innovativeness)?	What is the best reporting structure for an organization with certain characteristics (e.g., a start-up in a high-tech industry)?

Market Coordination and Network Structure

Price fixing conspirancies in the heavy electrical equipment industry

THE SOCIAL ORGANIZATION OF CONSPIRACY: ILLEGAL NETWORKS IN THE HEAVY ELECTRICAL EQUIPMENT INDUSTRY*

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University of Chicago

ROBERT R. FAULKNER
University of Massachusetts

We analyze the social organization of three well-known price-fixing conspiracies in the heavy electrical equipment industry. Although aspects of collusion have been studied by industrial organization economists and organizational criminologists, the organization of conspiracies has remained virtually unexplored. Using archival data, we reconstruct the actual communication networks involved in conspiracies in switchgear, transformers, and turbines. We find that the structure of illegal networks is driven primarily by the need to maximize concealment, rather than the need to maximize efficiency. However, network structure is also contingent on information-processing requirements imposed by product and market characteristics. Our individual-level model predicts verdict (guilt or innocence), sentence, and fine as functions of personal centrality in the illegal network, network structure, management level, and company size.

"People of the same trade seldom meet together but the conversation ends in a conspiracy against the public, or in some diversion to raise prices."

—*Adam Smith,* Wealth of Nations

"The fact that secrets do not remain guarded forever is the weakness of the secret society."

—*Georg Simmel,* The Secret Society

(Pfeffer 1987; Pfeffer and Salancik 1978; Burt 1983), direct manipulation of market ties (Baker 1990), and embeddeding business decisions in social relationships (Granovetter 1985). These market-restricting tactics are legal, but business organizations also indulge in practices proscribed by law that flagrantly subvert the market mechanism.

We analyze the social organization of a prevalent illegal corporate practice—price-fixing.

Source is [1]

Key features of the case

- **Scope of the business case**: the case deals with the organization of three well-known price-fixing conspiracies in the heavy electrical equipment industry
- **Relationship under investigation**: the information exchange network among the individuals involved in the price-fixing conspiracy
- **Outcomes of interest**:
  - Coordination among the conspirators
  - Concealment of the conspiracy

Market Coordination and Network Structure

Background: the origin price-fixing conspiracy

- Collusive agreements in the heavy electrical equipment industry go back to the 1880s, but the price-fixing *"schemes of the 1950s were given special impetus when repeated episodes of price warfare proved incompatible with top management demands for higher profits"* (Scherer 1980, p. 170).
- Top executives imposed unrealistic profit objectives in an industry characterized by chronic overcapacity, increasing foreign competition, and stagnating demand (Ohio Valley 1965, p. 939)
- To cope, managers decided to conspire rather than compete. Their elaborate conspiracy involved as many as 40 manufacturers and included more than 20 product lines, with total annual sales over $2 billion. The conspiracy was pervasive and long-lasting; it became, insiders said, a *"way of life"* (U.S. Senate Committee on the Judiciary 1961, pp. 16879-84.

Market Coordination and Network Structure

The manifestation of price-fixing conspiracy

> *"The Tennessee Valley Authority's (TVA) planning in 1958 for the Colbert Steam Plant exposed the conspiracy. The TVA complained about possible bid rigging to the U.S. Justice Department because it had received identical or nearly identical bids for electrical equipment, ranging from $3 for insulators to $17,402,300 for a 500,000 kilowatt steam turbine generator (Walton and Cleveland 1964, pp. 24-29). The Justice Department's investigation in 1959 revealed extensive collusion and grand jury indictments followed in 1960. The U.S. Senate Committee on the Judiciary, Sub-committee on Antitrust and Monopoly (the Kefauver Committee), held hearings on admin- istered prices in April, May, and June 1961."*

Source [1, page 838]

Market Coordination and Network Structure

The object of the price-fixing conspirancy

Switchgears

Transfomers

Steam turbine generator

Market Coordination and Network Structure

Network structure promoting concealment

Proposition 1

The need for secrecy lead conspirators to conceal their activities by creating sparse and decentralized networks.

Market Coordination and Network Structure

Network structure promoting concealment

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Argument for Proposition 1

Decentralization or ‘compartmental insulation’ limits exposure, making it difficult to uncover an entire network, particularly its leader

Market Coordination and Network Structure

Network structure promoting concealment

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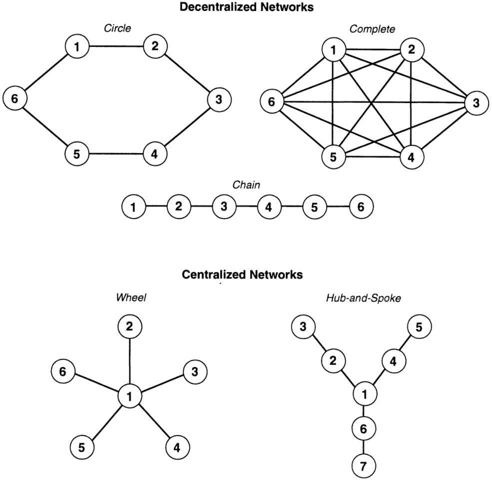
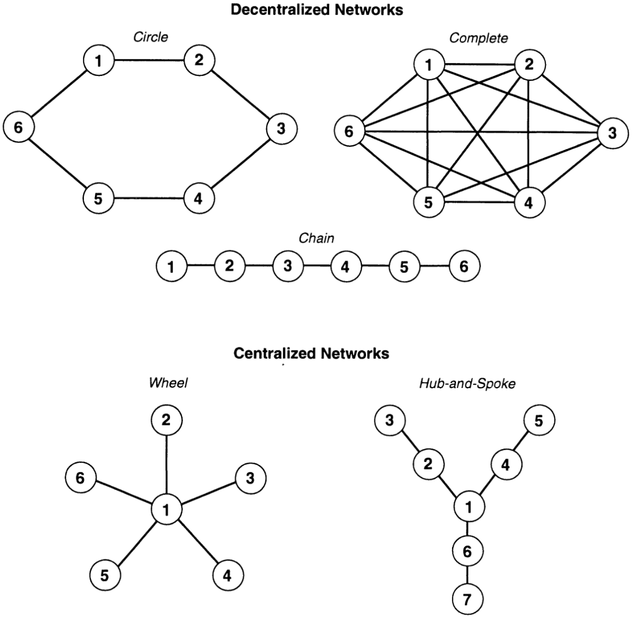


Source [1, page 849]


Decentralized Networks
Circle
Complete
Chain
Centralized Networks
Wheel
Hub-and-Spoke

Market Coordination and Network Structure

Network structure promoting coordination

Proposition 2

The conspiracies with low information-processing requirements — switchgear and transformers — exhibit centralize communication networks. The conspiracy with high information-process- ing requirements — turbines — should exhibit decentralized communication networks

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Argument for Proposition 2

Experimental research on small groups has found that simple, routine, unambiguous tasks are performed more efficiently in centralized structures, while difficult, complex, ambiguous tasks are performed more efficiently in decentralized structures.

Market Coordination and Network Structure

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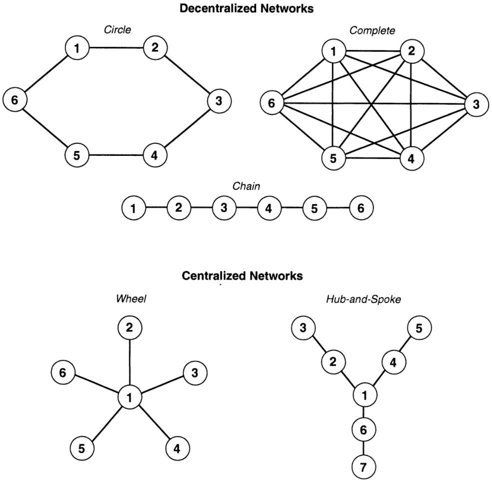

Source [1, page 849]

Market Coordination and Network Structure

Which is the best network structure to achieve coordination in fix-pricing conspiracy?

Organization Objective	Information-Processing Requirement	
	High	Low
Concealment	Decentralized networks	Decentralized networks
Coordination	Decentralized networks	Centralized networks

Figure 1. Concealment Versus Coordination: Theoretical Expectations

Source [1, page 845]

Table 1. Network Characteristics and Outcomes for Three Price-Fixing Conspiracies

Network Characteristic and Outcome	Conspiracy: Switchgear	Conspiracy: Transformers	Conspiracy: Turbines
Network Characteristic			
Size (number of participants)	33	21	24
Density	23.3	32.4	35.5
Nieminen graph centralization (degree)	41.7	36.1	51.4
Freeman graph centralization (betweenness)	21.3	17.6	24.2
Sabidussi graph centralization (farness)	39.0	37.4	60.8
Outcome			
Percent guilty	66.7	52.4	16.7***
Recommended sentence (in months)	1.43	2.64	1.25
Imposed sentence (in months)	.57	.82	.75
Time served (in months)	.10	.18	.25
Recommended fine (in dollars)	$2.33	$2.95	$5.25***
Imposed fine (in dollars)	$2.17	$2.91	$4.50*

* $p < .05$ *** $p < .001$ (one-way ANOVA)

Note: All outcomes except verdict are averages based on guilty verdicts.

Source [1, page 851]

Market Coordination and Network Structure

Results

Table 1. Network Characteristics and Outcomes for Three Price-Fixing Conspiracies

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Source [1, page 851]

Table 2. Logistic Coefficients for Regression of Verdict on Personal Attributes and Network Variables: Participants in Three Price-Fixing Conspiracies

Independent Variable	Model 1
Constant	-3.834* (1.890)
General Electric (1 = GE; 0 = otherwise)	-.561 (.769)
Westinghouse (1 = Westinghouse; 0 = otherwise)	-.060 (.875)
Turbines conspiracy (1 = turbines; 0 = switchgear or transformers)	-3.416* (1.471)
Top executive (1 = top executive; 0 = otherwise)	.281 (.753)
Middle manager (1 = middle manager; 0 = otherwise)	1.643† (.927)
Turbines conspiracy × top executive	4.020* (2.019)
Degree centrality	.381** (.138)
Betweenness centrality	.002 (.021)
Farness centrality	.020 (.019)
Number of participants	69

† $p < .05$ (one-tailed test)

* $p < .05$ ** $p < .01$ (two-tailed test)

Note: Numbers in parentheses are standard errors. This model correctly classifies 86.5 percent of those found guilty and 78.1 percent of those found not guilty. Overall, the model correcly classifies 82.6 percent.

Source [1, page 852]

References

[1] Wayne E Baker and Robert R Faulkner. "The Social Organization of Conspiracy: Illegal Networks in the Heavy Electrical Equipment Industry". In: *American Sociological Review* 58.6 (1993), p. 837.

[2] Ronald S Burt. *Brokerage and Closure: An Introduction to Social Capital*. OUP Oxford, 2007.

[3] John Scott and Peter J Carrington. *The SAGE Handbook of Social Network Analysis*. SAGE publications, 2011.

[4] Angelika Steger and Nicholas C Wormald. "Generating Random Regular Graphs Quickly". In: *Combinatorics, Probability and Computing* 8.4 (1999), pp. 377–396.

[5] Duncan J Watts and Steven H Strogatz. "Collective Dynamics of 'Small-World' Networks". In: *nature* 393.6684 (1998), pp. 440–442.