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# Influence in Corporate Networks: An Examination of Four Measures

Mark S. Mizruchi and David Bunting

This study evaluates four quantitative measures of influence in networks of large corporations: (1) the absolute number of interlocks; (2) the Bonacich centrality index; (3) a modification of the Bonacich index using strong ties only; and (4) a further modification of the Bonacich index using strong ties weighted for directionality. These measures are applied to data from a sample of large American corporations in 1904, and the results are compared with the historical record. Results from the more sophisticated measures are shown to more closely resemble historical accounts of the period. Implications of these findings for studies of intercorporate relations are discussed. •

## BACKGROUND

### The Corporate Control Debate

The issue of power among large corporations has its roots in the classic study by Berle and Means (1968) in 1932. These authors argued that as corporations grew, the large blocks of stock once held by wealthy families gradually dissipated. The result was a separation of stock ownership from corporate control. According to Berle and Means, effective control was increasingly held by insiders, those who ran the daily activities of the firm. This view was accepted by nearly all organization theorists at least until the late 1960s. However, in recent years it has been challenged on both theoretical and empirical grounds (Zeitlin, 1974; Mintz, 1978; Useem, 1980).

Most studies of corporate control have employed stock ownership data to locate control (Temporary National Economic Committee, 1940; Villarejo, 1961; Patman Committee, 1968; Larner, 1970; Burch, 1972; Kotz, 1978). The problem with this approach is that although one can often find who holds the largest block of stock, this information may not reveal who in fact controls the firm. For example, in 1962 Howard Hughes owned 78 percent of TWA stock, but TWA was in fact controlled by a consortium of banks and insurance companies (Fitch and Oppenheimer, 1970). In 1901, J. P. Morgan & Co. owned a negligible fraction of U.S. Steel stock and yet completely dominated the firm (Corey, 1930). Controlling elements in both cases were other corporations, suggesting that it may be profitable to search for control in the structure of relations among the corporations. This was done to some extent by the Patman Committee (1968) and Kotz (1978) who reintroduced the idea of bank control over non-financials (Brandeis, 1914; Lenin, 1975). However, both studies used the individual firm as the unit of analysis. They located the largest stockholder and classified the firm on that basis. This approach failed to view the firm in the context of a corporate system in which multi-dimensional control relations often exist.

### Influence and Interlocking Directorates

A number of studies have employed interlocking board memberships among corporations as indicators of control (Fennema and Schijf, 1979; Useem, 1979; Pennings, 1980). Such studies go back as far as the Pujos Report (U.S. Congress, 1913), a congressional investigation into corporate concentration. Interlocks have also been used as indicators of control by Brandeis (1914), the National Resources Committee (1939), and more recently by Perlo (1957), Fitch and Oppenheimer (1970), and

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Knowles (1973). Control through interlocking board memberships was a practice widely recognized by historians of the early 1900s. Investment banks and other firms would place representatives on the boards of corporations they controlled, as J. P. Morgan & Co. did with U.S. Steel (see Mizruchi, 1981, for a review of this literature). It is current practice to recognize that powerful interests in corporations are entitled to board representation. Such interests include large stockholders, major lenders, customers, and suppliers (see Mace, 1971; *Business Week*, 1980a; 1980b, for some examples).

Since corporate boards typically include from 10 to 25 or more members, however, having two or three representatives does not ensure control. Furthermore, several theorists have argued that interlocking involves "cooptation" of outside interests rather than submission to them (Thompson and McEwen, 1958; Pfeffer, 1972; Allen, 1974; Pfeffer and Salancik, 1978). Thus, since boards are often represented by a plurality of interests, a more accurate description of interlocking would be that it permits influence rather than control. Influence has been defined as leadership ability in situations of collective activity and as the ability to affect the outcome of events (Hopkins, 1964). The definition employed here is the ability of an organization to exercise power over another organization, power being the ability to realize one's goals even in the face of external opposition (Weber, 1947: 152). Control is defined as the ability to determine the long-run policies of a firm (Juran and Loudon, 1966: 48; Kotz, 1978). Of course, influence and control often correspond, but influence need not constitute control, and thus it is the more general term.

### **Measuring Influence with Interlocks**

It follows from the above discussion that one way of measuring influence in networks of corporations is to sum each firm's number of interlocks. Those firms with the highest number of interlocks would be the most influential in the network. A number of criticisms have been levelled against this approach, however. First, it ignores the considerable variance in the number of directors per company and, therefore, the potential of a company to establish affiliations (Bonacich, 1972a). Second, it implicitly weights all interlocks equally and assumes a linear relationship between interlocks and other organizational characteristics. Third, it ignores the direction of interlocking. Which corporation does an interlocked director represent? Some companies may have a large number of interlocks because they are influential, while others may simply be coopted. Finally, this approach ultimately treats the individual firm as the unit of analysis. Knowledge of a firm's number of interlocks may tell little about where it stands in relation to other firms in its interorganizational network. One firm may have five interlocks with five heavily-interlocked firms while another may have ten interlocks with two relatively obscure firms.

### **Centrality and Influence**

Recently, considerable effort has been devoted to developing more sophisticated models of network relationships. Developments derived from small-group network research include the use of multidimensional scaling (Levine, 1972; Laumann and Pappi, 1976; Galaskiewicz, 1979), factor analysis (Allen, 1978), input-output and differential equation models (Burt,

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1979), and the blockmodel approach (Breiger, Boorman, and Arabie, 1975; White, Boorman, and Breiger, 1976; Arabie and Boorman, 1977; Breiger, 1977). (For an extensive review of the various network models, see Burt, 1980.) These techniques are only beginning to be applied to interorganizational networks. One technique that has been used almost exclusively as a measure of influence in corporate networks is the measure of centrality developed by Bonacich (1972a, 1972b) and modified for corporate network research by Bearden et al. (1975) and Mariolis, Schwartz, and Mintz (1979). This measure utilizes the classic sociometric concept of centrality. A point (e.g., a company) is central to the extent that: (1) a large number of other points can be reached in a small number of steps (Bavelas, 1948, 1950; Mackenzie, 1966; Nieminen, 1973; Freeman, 1977) and (2) paths from other points must go through it in order to reach third points (Freeman, 1979). In the present study, the Bonacich centrality measure was chosen over other similar measures because it lends itself to a unique set of matrix manipulations.

Centrality is defined operationally as a function of a point's structural position within a set of relations. However, numerous studies have found a strong relationship between centrality and other characteristics. Leavitt (1951), for example, found that centrality in communication networks was strongly correlated with variables such as satisfaction in group activity, leadership, and influence on the outcome of events. Using four types of communication structures, he found that the differences between the most central figure and the others increased with increasing hierarchy of each structure. Studies by Bass (1949), Strodbeck (1954), and March (1956) provided similar evidence of the relation between centrality (as measured by time spent interacting or by acts initiated) and influence. In a summary of this evidence in connection with a study of his own, Hopkins (1964) concluded that centrality was a strong predictor of both influence and rank (leadership). In his study, the correlation between centrality and influence was .82.

Similar results have been found in interorganizational studies such as those by Perrucci and Pilisuk (1970), Laumann and Pappi (1976), Galaskiewicz (1979), and Rogers and Maas (1979), which found strong relationships between reputed influence and centrality in interorganizational networks.

## **METHOD**

### **Testing the Validity of Centrality as a Measure of Influence**

The evidence from both small group and interorganizational research thus suggests that network centrality is strongly related to a number of hierarchical characteristics, including influence, leadership, and status. This in turn suggests that a centrality measure could serve as an indicator of influence among large corporations, but it has not been demonstrated that centrality measures produce results substantially different from results based on number of interlocks. Although Mariolis (1975) produced some different results, his data were from recent years and, thus, interpretation was difficult. The present study addresses this problem by choosing data that are more easily interpretable and for which reliable independent evidence exists. Using these data, the Bonacich centrality index

was compared to a simple count of number of corporate interlocks. In addition, two modifications of the Bonacich centrality index were tested.

The number of interlocks and the three measures of centrality were calculated for 166 large American corporations from the year 1904. Next, these four measures were compared with historical accounts of the period to determine which provided the most accurate measure of corporate influence. Unlike recent years, in which there has been sharp controversy over the relative power of various corporations (especially banks), the period around the turn of the century was characterized by an almost uniform consensus concerning the power of certain groups in the economy.

### Data Selection

The year 1904 was chosen for a number of reasons. First, it was part of the era of finance capitalism, when no important regulatory constraints influenced affiliations. Second, corporate influence had begun to be measured by affiliations; stock ownership was no longer considered the primary basis of corporate control (Corey, 1930:284). Because small stockholders were widely dispersed, major capitalists found it relatively easy to elect themselves or their representatives to a directorship of nearly any large company (Bunting, 1979). Finally, during this period there was an active group of business writers and academicians who were concerned about the growing concentration of control of American finance and industry. These writers, who contributed to publications such as *The Wall Street Journal*, *Railway World*, and *Atlantic Monthly*, were in no sense antagonistic to big business. Instead, they urged curtailment of certain activities so that business could operate unhampered by visionary social legislation. 1904 was chosen over other years in the same period because it was the year of greatest interlocking.

Data used in the study consisted of officer and director interlocks for 166 large American corporations in 1904. The sample included the largest 99 industrials, 25 transports, 10 insurance companies, 20 banks, and 12 large investment houses. Because asset values were not generally available, size was determined by capitalization (par value of issued stock plus funded debt). Investment banks were selected subjectively, since they disclosed no financial information. Primary data sources were financial manuals such as the *Manual of Statistics*, *Moody's*, *Banker's Directory*, and the *New York Stock Exchange Directory*, supplemented by *Who Was Who* and the *Dictionary of American Biography*. For further discussion of data selection see Bunting and Barbour (1971) and Mizruchi (1981).

### The Bonacich Centrality Index

Based in part on the earlier work of Katz (1953) and Hubbell (1965), Bonacich (1972a, 1972b) argued that a point's centrality in a network should depend on three criteria: (1) the number of links to other points; (2) the intensity of the links; and (3) the centrality of those with whom one is linked. For organizations, the number of potential linkers in each unit can be accounted for in the measure of intensity. If  $R$  is a matrix of relationships ( $r$ ) and  $C$  is a point's centrality, then for each point  $i$

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$$C_i = r_{i1}C_1 + r_{i2}C_2 + \dots + r_{in}C_n$$

or

$$C_i = \sum_{\substack{j=1 \\ j \neq i}}^N r_{ij} * C_j ,$$

where  $N$  = number of organizations linked with  $i$ ;  $r_{ij}$  = intensity of the particular link;  $C_j$  = centrality of the organizations linked with  $i$ .

To find  $C_i$ , a matrix of overlaps ( $R$ ) must be computed. There are several possible measures of intensity that can be used (for a discussion of these, see Mariolis, Schwartz, and Mintz, 1979). In the present study, the measure developed by Mariolis (1975) was used:

$$r_{ij} = \frac{b_{ij}}{\sqrt{d_i * d_j}} ,$$

where  $b_{ij}$  = number of members in common, and  $d_i$  and  $d_j$  = number of potential interlockers from each organization.

This measure has three advantages: First, following Bonacich, it controls for the number of potential affiliations that a company might possess; for example, a company with forty directors on its board has more opportunities to interlock than one with eight. Second, using the square root of  $d_i * d_j$  minimizes the effect of increasing board size, because the importance of each additional member decreases; for example, the difference between boards of four and three members is much greater than that between boards of 17 and 16 members. Finally, this figure is equivalent to a Pearson product-moment correlation statistic prior to subtracting out the means; hence,  $r_{ij}$  can be interpreted as a correlation coefficient.

Centrality scores were calculated as a system of simultaneous linear equations in the form  $C = RC$  where  $C$  is an  $N \times 1$  vector of centrality scores ( $N$  = the number of points in the system) and  $R$  an  $N \times N$  correlation matrix containing the measures of overlap  $r_{ij}$ . This equation, as it stands, has no solution. However, Bonacich (1972b) demonstrated that by multiplying  $C$  by the largest eigenvalue ( $\lambda$ ), so that  $\lambda C = RC$ , an approximation can be reached. Hence:

$$C_i = \frac{1}{\lambda} \sum_{\substack{j=1 \\ j \neq i}}^N r_{ij} * C_j ,$$

where  $\lambda$  = the eigenvalue of the first principal component.

Although it has a different purpose, this calculation is identical to factor analysis. The first eigenvector will have all non-negative or non-positive values, and there will be as many all-same-sign eigenvectors as there are discrete components in the graph. All other eigenvectors will have some negative and some positive values. Because the calculation produces one more unknown than the number of equations, the actual value of the centrality scores is arbitrary. The one arbitrary parameter is selected such that the firm with the highest centrality receives a score of 1.0. Other scores then range from 0 to 1.

The equations are solved by means of the power method for extracting eigenvectors (Noble, 1969: 299–300). In some cases, two firms are so heavily interlocked with each other that their centrality scores become inflated, thus distorting the entire system. Because such situations are rare yet have significant effects, the suggestion of Bearden et al. (1975) that the number of recorded interlocks in  $r_{ij}$  be limited to three has been followed.

### Measuring Strength of Ties

The Bonacich centrality measure fails to distinguish between different types of interlocks. To correct this problem, a measure incorporating Granovetter's distinction between strong and weak ties, based on the frequency and intensity of interaction (Granovetter, 1973), may be applied. This concept has been used to indicate the significance of a particular interlock (Bearden et al., 1975). Strong ties are indicated by a director's principal affiliation, usually determined by whether he or she is an officer of the firm (Warner and Unwalla, 1967). When an officer of corporation A is a director of B and C, there are A-B and A-C links, but a B-C link also occurs. The A-B and A-C links are designated strong ties and the B-C link a weak tie. Weak ties may be important, since in some cases they provide bridges between cliques. However, when given the same weight as strong ties, they may create noise in the system by overstating the number of affiliations between companies. By removing the weak ties, a clearer picture of subgroups within the network may be gained. Although the exclusion of weak ties produces a different correlation matrix from the original  $R$  matrix, the equations for centrality are solved in the same manner.

### The Directional Strong Tie Measure

An added dimension may be gained by accounting for the direction of interlocks (Mintz, 1978). In A-B and A-C links where the person is an officer of firm A, the interlocks can be viewed as A "sending" to B and C. This distinction is incorporated into the centrality index by means of a weighted measure of  $r_{ij}$ :

$$\text{sending: } r_{ij} = \frac{W_s * S_{ij}}{\sqrt{d_i * d_j}}$$

where  $S_{ij}$  = number of officers of firm  $i$  who sit on the board of firm  $j$ ;

$$\text{receiving: } r_{ij} = \frac{W_r * T_{ij}}{\sqrt{d_i * d_j}}$$

where  $T_{ij}$  = number of officers of firm  $j$  who sit on the board of firm  $i$ ;

$$\text{exchange of officers: } r_{ij} = \frac{W_s * S_{ij} + W_r * T_{ij}}{\sqrt{d_i * d_j}}$$

where  $W_s$  = weight of sender;  $W_r$  = weight of receiver;  $W_s + W_r = 1$ ; we have set  $W_s = .9$  and  $W_r = .1$ .

The assigned weights are, of course, arbitrary. They are based on the assumption that A exercises a disproportionate share of influence over B but that this influence is not absolute. As with most measures of this type, their value is determined by the tenability of the results they produce.

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The directional matrix is asymmetric such that  $R \neq R'$  while the Bonacich centrality measure is based on the assumption of a symmetric matrix. The problem with the asymmetric matrix is that more than one solution to the equation is possible. The solution chosen was the largest eigenvector, as with the symmetric matrix. Other solutions would be extremely difficult to extract. Furthermore, the chosen solution checked, i.e., the results were correct according to the formula for centrality. In addition, the results based on this measure were shown to correspond closely with the historical record. Nevertheless, further work is needed to extract other possible roots of this equation for asymmetric matrices. Bonacich has devised a technique to make the matrix symmetric by multiplying  $R$  by  $R'$  and then treating this product as  $R$  in the original equation. (We thank Peter Mariolis for calling our attention to this idea.) The consequences of this modification are under study.

The continued use of the term "centrality" to describe the directional measure may be confusing to some readers, in particular those who, because of the asymmetry, find this measure similar to Moreno's concept of "prestige" (Moreno, 1953). In Moreno's concept, and in popularity measures in general, those with high status are chosen as friends more frequently than they choose others as friends (Burt, 1980). In our terms, these individuals receive more interlocks than they send. In the present analysis of corporate influence, it is argued that those with high influence send more than they receive. The term "centrality" is used even in the directional measure because directional centrality is based on the same structural view of centrality as the full matrix measure. The only difference is that in the directional measure a firm's centrality is weighted based on the particular character of different interlocks. The resource dependence position is closer to the concept of interlocking as prestige because the influential organization is that which has the ability to coopt other organizations (Pfeffer and Salancik, 1978). Thus, the more influential corporation receives more interlocks than it sends. However, what the receiving corporation has, first and foremost, is control over crucial resources. Prestige, if it in fact accompanies centrality in this case, is a secondary concern.

Furthermore, this position is not contradictory to a resource dependence perspective, since control over specific resources, such as loan capital, is frequently what allows a firm a seat on another firm's board. As Aldrich (1979:296) has pointed out, "the term cooptation may involve too much 'voluntarism' in some cases, such as when taking on a director from a bank is the price a firm pays for having its corporate bonds underwritten." Historically, there is far more evidence to support the "sending as influence" perspective advanced here. The evidence for recent years is not conclusive either way. However, one of the major advantages of this measure is that it allows for flexibility in response to changing theoretical requirements. The weights for sending and receiving can be altered in any way, or even reversed, to suit alternative theoretical criteria.

## **RESULTS**

Four measures of relative influence in corporate networks have been presented. These are: (1) a measure based on absolute number of interlocks; (2) the Bonacich centrality index, based

Table 1

**Pearson Product-Moment Correlations among Four Measures of Centrality**

	1	2	3
1. Number of interlocks			
2. Full network centrality	.89		
3. Strong tie network centrality	.71	.84	
4. Directional strong tie network centrality	.49	.63	.91

on the full network of all interlocks; (3) a centrality index based on strong ties only; and (4) a centrality index based on strong ties weighted for directionality.

Table 1 lists the Pearson product-moment correlation coefficients for the four measures for all 166 firms in the sample. Although the relation between the number of interlocks and full network centrality was quite strong (.89), the results of the more complex measures were increasingly different from those based on the number of interlocks.

Given the substantial differences in results, the historical record must be examined to determine the efficacy of each of the four measures. Table 2 presents the twenty most central corporations, based on each of the four measures, as well as their locus of control as reported by observers of the period. Control is treated here as the purest form of influence. Firms that control other firms will be relatively influential, while controlled firms will be less influential. Control was defined in terms of recognized leadership and commonality of interests, rather than in terms of legal criteria such as stock ownership. Control in this sense is very difficult to define; nevertheless it was widely thought to exist in 1904. One writer clearly described this form of control when discussing J. P. Morgan's power over large New York banks in 1910:

Many of the banks are popularly supposed to be controlled by stock ownership in the Morgan house. That does not matter. Nobody cares very much who collects the dividends on the stocks of these banks. The important question, from the standpoint of Mr. Morgan and the standpoint of the people is rather: "Who runs this bank?" . . . Perhaps the Morgan-Baker group, combined, does control the First National and the Chase National. I don't see that it makes any difference whether they do or not, so long as they can say to these banks, alike in crisis or in fair weather: "Do this!" — and the banks do it (Keys, 1910:12621).

The corporations under study were classified in three categories as "controlling," "allied," or "controlled." Companies in the first category included the leading members of the two major financial groups of the time: J. P. Morgan & Co., on the one hand, and the "KL-SO-H" alliance of Jacob Schiff of Kuhn, Loeb & Co., William Rockefeller of Standard Oil, James Stillman of National City Bank, and Edward H. Harriman of Union Pacific, on the other. Companies such as Rock Island and Speyer & Co., which were independent of external control and relatively isolated from the above two financial groups, were also placed in the first category. Companies in the second category included those such as George F. Baker's First National Bank and James J. Hill's Great Northern-Northern Pacific complex, both of which, although somewhat subordinate to Morgan, were essentially operated independently and controlled other firms in their own right. The final category includes controlled companies such as U. S. Steel (under Morgan

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Table 2

### Most Influential Companies in 1904

I	Rank*		D	Name	Control	Sources†
	F	S				
—	—	1	1	J.P. Morgan & Co.	Morgan	
12	10	3	2	New York Life	Morgan controlled	("Q.P.," 1905–1906a: 7317)
13	5	2	3	Great Nor. & Nor. Pacific R.R.	Morgan allied	(Cunniff, 1902: 1777)
20	11	5	4	International Harvester	Morgan controlled	(Pratt, 1903–1904: 4264)
14	15	7	5	U.S. Trust	KL-SO-H controlled	(Bullock, 1903: 187)
10	7	6	6	National City Bank	KL-SO-H	(Bullock, 1903: 187)
18	8	4	7	First National Bank (NY)	Morgan allied	(Bullock, 1903: 187)
—	—	9	8	Standard Oil	KL-SO-H	
—	—	15	9	Central Trust	Morgan controlled	(Pratt, 1903–1904: 4264)
—	—	14	10	Title Guarantee & Trust	Morgan controlled	(Keller, 1963: 141)
7	9	8	11	New York Trust	Morgan controlled	(Keller, 1963: 154)
—	—	20	12	Kuhn, Loeb & Co.	KL-SO-H	
15	13	16	13	Chicago & Alton R.R.	KL-SO-H controlled	(Keys, 1905: 6310)
9	12	12	14	Union Pacific R.R.	KL-SO-H	(Cunniff, 1902: 1777)
4	18	13	15	Mutual Life	Morgan controlled	("Q.P.," 1905–1906b: 7385)
—	20	17	16	Amalgamated Copper	KL-SO-H controlled	(Pratt, 1903–1904: 4265)
—	—	—	17	Speyer & Co.	Independent	
—	—	—	18	Winslow, Lanier & Co.	Independent	
—	—	—	19	Rock Island R.R.	Independent	(Moody and Turner, 1911: 420)
—	—	—	20	Seaboard Air Line R.R.	Independent	(Newcomb, 1901: 166)
3	3	10	—	U.S. Steel	Morgan controlled	(Pratt, 1903–1904: 4264)
1	6	11	—	National Bank of Commerce	Morgan controlled	(Keys, 1907–1908: 9530)
6	1	18	—	Erie R.R.	Morgan controlled	(Cunniff, 1902: 1777)
11	2	19	—	New York Central R.R.	Morgan controlled	(Keys, 1906–1907: 8439)
5	4	—	—	Baltimore & Ohio R.R.	Penn controlled	(Daggett, 1908: 32)
—	14	—	—	Lehigh & Wilkes-Barre Coal	Morgan controlled	(Cunniff, 1902: 1777)
19	16	—	—	Reading R.R.	Morgan controlled	(Newcomb, 1901: 166)
16	17	—	—	Chicago & Northwestern R.R.	Morgan controlled	(Cunniff, 1902: 1777)
17	19	—	—	Lehigh Valley R.R.	Morgan controlled	(Cunniff, 1902: 1777)
2	—	—	—	Equitable Life	KL-SO-H controlled	("Q.P.," 1905–1906a: 7317)
8	—	—	—	Equitable Trust	KL-SO-H controlled	(Keller, 1963: 147)

Note: Corporations ranking in the top 20 according to one or more of the four measures are listed.

\*I=number of interlocks measure; F=full network centrality measure; S=strong tie network centrality measure;

D=directional strong tie network centrality measure.

†See Appendix for a reference list of the sources used.

domination), Amalgamated Copper (under Standard Oil-National City control), and various railroads controlled by Morgan.

Turning now to the companies listed in Table 2, it is apparent that most companies ranked high in number of interlocks (I) were controlled by some other firm. Included in this group were National Bank of Commerce (an insurance bank partly owned by Equitable and Mutual but dominated by J. P. Morgan), Equitable Life and Equitable Trust, so heavily interlocked with each other (18 times) as to overstate their actual importance in the network, and four railroads either reorganized by Morgan (Erie, Reading, and Lehigh Valley) or controlled in his interest (the Chicago and Northwestern, by the Vanderbilts). The list contains some major controlling concerns such as First National Bank, National City Bank, and Union Pacific, but three key documented sources of influence have been omitted: J. P. Morgan & Co.; Kuhn, Loeb & Co.; and Standard Oil. Corporations known to be dominated by Morgan or KL-SO-H interests were included, yet the controlling parties themselves were excluded.

The full network centrality measure (F) also suffered this flaw. Using this measure eliminated the Equitable Life-Trust combi-

nation from the list and increased the centrality of both the First National Bank and National City Bank. However, it also added Lehigh & Wilkes-Barre Coal, a captive anthracite company controlled by Reading through its subsidiary, Central of New Jersey Railroad. Still included were many controlled companies and still absent were the three major firms mentioned above. However, the strong tie measure (S) produced rankings much more consistent with the historical record. The various railroads known to be under financial dominance did not appear, and the three principal financial firms were all included. J. P. Morgan & Co. enters the list at the top, while Central Trust and Title Guarantee and Trust, two trust companies heavily involved in securities, enter in the lower half. KL-SO-H influence is explicitly recognized by the inclusion of both Kuhn, Loeb & Co., and Standard Oil, the principal members of the group. However, the strong tie measure still includes a number of companies known to be subsidiary to outside interests, for example, U.S. Steel and the National Bank of Commerce.

The best results were found when the directionality of intercorporate relationships was considered. This measure (D) identified the major members and their allies for both the Morgan and KL-SO-H groups while excluding dependent companies such as U.S. Steel and New York Central. Under this method, Morgan & Co. continues its top ranking, while Kuhn, Loeb & Co. was ranked twelfth. However, even this method showed controlled firms among the most central (e.g., International Harvester and Chicago & Alton). This suggests either that the method is still imperfect or that Morgan or KL-SO-H influence was not unilateral. Both the number of interlocks measure and the full network centrality measure showed only four firms in the top twenty that could be considered independent of control by another corporation. The strong tie measure showed seven independents among the top twenty while the directional strong tie measure showed eleven. This further suggests that the directional strong tie measure is the most capable of identifying powerful firms in the corporate world.

Because of the high correlation between the number of interlocks and the full network centrality score, it appeared that the number of sending interlocks might be used interchangeably with directional centrality scores. The correlation between directional interlocking and directional centrality in these data was .87, and the correlation between all interlocks and directional interlocks was .62. Thus, while it is true that most of the variation in directional centrality was accounted for by directional interlocking, there are two reasons why the centrality score is preferable. First, the interlock measure does not control for number of directors, weights all interlocks evenly, and treats the individual firm as the unit of analysis. Second, there were a number of cases in which the superiority of the centrality measure was clearly evident. For example, Kuhn, Loeb & Co. had only 9.0 directional interlocks but was twelfth in centrality. Equitable Life had 14.5 directional interlocks but was ranked only thirty-first in centrality. There are occasions in which unusually high centrality was derived from one particular interlock with another highly central firm. Mintz and Schwartz (1978) devised a technique for "denormalizing" the network by removing from a firm's centrality score any link with firms whose centrality is more than a certain proportion (80 percent in their

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study) of its centrality. This technique did not produce an appreciable change in the rankings of the most central firms in the present study.

### Centrality by Sector

To determine the relative influence of different sectors of the economy, an analysis of variance in centrality by sector was conducted (see Table 3). In the full network, railroads as a group were highly central and industrials had low centrality. Insurance companies, investment banks, and commercial banks, which were treated together as financials, accounted for only 6.2 percent of the variation, and .9 percent came from a negative direction because of the low centrality of investment banks. In all, 28.1 percent of the variation in centrality was accounted for by type of firm. Results were different for the strong tie and directional strong tie networks. Although industrial centrality remained low, railroad centrality dropped sharply from 14.6 percent of the total variation to 2.7 percent in the strong tie network and .1 percent in the directional network. Financials, meanwhile, accounted for 9.3 percent and 11.4 percent of the variation, all in a positive direction, a sharp increase from their position in the full network. The five sectors combined accounted for 19.4 percent and 17.5 percent of the total variance, somewhat less than for the full network.

These percentages are still significantly larger than Mariolis' (1975) findings for corporations in 1969. For Mariolis, type of firm accounted for only 5.2 percent of the variation in centrality in his full network, 4.2 percent of which was accounted for by commercial banks alone. An analysis of variance of number of

Table 3

<b>Analysis of Variance of Centrality by Sector</b>			
<b>Sector (N)</b>	<b>Mean</b>	<b>S.D.</b>	<b>% Total SS accounted For</b>
<b>Full Network</b>			
Industrials (99)	.116	.180	7.3
Transports (25)	.468	.307	14.6
Insurances (10)	.241	.315	.1
Investment banks (12)	.114	.182	.9
Banks (20)	.381	.290	5.2
Total (166)	.208	.265	28.1
<b>Strong Tie Network</b>			
Industrials (78)	.098	.139	7.4
Transports (24)	.256	.196	2.7
Insurances (7)	.281	.314	1.4
Investment banks (11)	.206	.286	.2
Banks (17)	.338	.252	7.7
Total (137)	.174	.209	19.4
<b>Directional Strong Tie Network</b>			
Industrials (78)	.056	.110	6.0
Transports (24)	.134	.171	.1
Insurances (7)	.227	.315	1.7
Investment banks (11)	.234	.297	3.0
Banks (17)	.257	.247	6.7
Total (137)	.118	.190	17.5

interlocks by sector in the present data produced an explained variation of 27.5 percent. Industrials accounted for 7 percent of total variation, railroads for 9.8 percent, insurances .9 percent, investment banks 1.9 percent, and banks 7.7 percent.

This pattern suggests that the high full network centrality of railroads was a result of the frequent placement of financial representatives on railroads' boards, as well as the latter's high proportion of neutral interlocks. This is consistent with historical evidence of the importance of railroads at the turn of the century and their heavy dependence on financials. It is also consistent with evidence of the pivotal role played by financial institutions in the economy. Thus, from analysis of both the most central corporations and the network as a whole, the measure that considers network centrality, eliminates weak ties, and weights interlocks according to direction provides the most accurate measure of influence among corporations.

## CONCLUSION

The above results strongly suggest that studies of network centrality and influence will be strengthened by accounting for the direction of network ties. In studies employing multiple regression and other multivariate techniques, the use of centrality scores rather than interlocks as variables might improve the predictability of models of corporate growth, profitability, debt-equity ratios, and other characteristics of corporations.

These findings also have implications for the debate over corporate control. The historical consensus is that financial corporations exercised tremendous power around the turn of the twentieth century. This view corresponds very closely with our data on directional centrality. A number of studies have documented the high centrality of financials in recent years (Dooley, 1969; Levine, 1972; Bearden et al., 1975; Mariolis, 1975; Sonquist and Koenig, 1976; Mizruchi, 1981), but systematic, independent evidence for their influence has been difficult to assemble. This study suggests that a centrality measure based on a network of strong ties weighted for directionality would prove useful in assembling this evidence.

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