A STUDY OF CHANGE IN A REGIONAL CORPORATE NETWORK*

by

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ABSTRACT

Recent studies of interorganizational networks have frequently overlooked two important phenomena - the structural properties of the entire network and changes in the structure of the network over time. This paper suggests a strategy for exploring structural changes using discrete time Markov chains.

Two dimensions of interorganizational network change are described and reconceptualized in terms of the stochastic models developed by Wasserman (1978a and 1979). The first dimension is a tendency for linkages in a network to be reciprocated. A second dimension is a tendency toward a hierarchy of actors. The methods outlined in this paper attempt to describe how these tendencies can be quantified in a rigorous manner.

To illustrate our methodology, data on the board linkages of twenty-seven public corporations in Minnesota are analyzed. Our study covers the years from 1969 to 1977. Markov chains, with structural parameters, are used to model the dyads, indegrees, and outdegrees of the corporate network. These parameters are estimated and evaluated, and conclusions about changes in the board interlock network are discussed.

A Study of Change in a Regional Corporate Network

While there is a growing consensus that the interorganizational network is now an important unit of analysis in organizational studies (see Perrow, 1979; Aldrich, 1979) there has been very little research on studying structural change in these networks (cf., Allen, 1974, 1978). One problem has been the identification of meaningful dimensions of change. At present, there are adequate methods to describe structural properties of interorganizational networks at one point in time (e.g., graph theory, hierarchical cluster analysis, blockmodels, and smallest space analysis); however, there has been no systematic effort to describe how interorganizational networks might change over time.[1]

Unfortunately, there are no theories in the formal organizations' literature that could guide this paper's efforts at developing a methodology to study interorganizational network change.[2] As a first attempt to develop a rigorous, inductive strategy for the study of change, we will borrow from the recent work of Wasserman (1978a, 1978b, 1979) on the application of Markov models to social networks. Other empirical applications of this technique are found in Wasserman (1978a).

Dimensions of Macro-Structural Change

Wasserman (1978a) has identified a number of parameters that can be estimated to describe change in a social network. By examining all the dyads in a network over time, a researcher may first pay attention to tendencies away from or towards reciprocity. More specifically, he or she might determine 1) if there is an increased probability of a linkage developing over time between units i and j when a linkage already exists from j to i; and 2) if there is a decreased probability of a linkage between i and j disappearing over time when a linkage from j to i is present. Wasserman (1979) suggests that we model each dyad as a Markov chain, theoretically specifying the probabilities of transitional change and estimating four substantive parameters that are combined to form these probabilities. The stochastic model for the dyad process is discussed below. Hallinan (1978) also studies change in dyads, but postulates no substantive model for this change.

Other parameters can be estimated that describe tendencies away from or toward hierarchy. A researcher might wish to see if there is a tendency for units which are central in the network to become more central.[3] More specifically, the researcher would determine if the total outflows and inflows of units at t_1 affect their subsequent outflows and inflows at t_2. Do units with largein- or outdegrees, corresponding to total inflows and outflows, tend to have even larger or smaller in-or outdegrees over time; i.e., do they become more central or more peripheral? These tendencies can also be quantified using Markov models.

To get an idea of how Wasserman's models may be used to study interorganizational networks, let us discuss them in terms of one common form of interorganizational network, a system of interlocking corporate boards. In the specific case of an interlocking directorate, a tendency towards reciprocity implies that someone from organization i may become a member of organization j's board if someone from j is already a member of i's board. In studying friendship ties the substantive interpretation of reciprocity effects is straightforward. Suppose an individual j chooses i as a friend at t_1. It is likely that i may choose j as a friend at t_2 - if you are a friend to someone they are likely to be a friend to you. However, in reference to a board linkage, the substantive meaning of reciprocity is not immediately obvious. On the one hand, if we view board linkages as only a means by which organizations routinize the exchange of technical information or secure scarce resources (see Allen, 1974; Mariolis, 1975; Aldrich, 1979), a move to reciprocate board memberships would seem to be superfluous. A single board interlock can operate just as effectively as a mutual interlock to communicate information or to negotiate a market transaction. On the other hand, if we view board linkages as a means by which organizations express moral or political support for one another (see Perrucci and Pilisuk, 1970; Laumann and Pappi, 1976), then a move towards reciprocity may be relevant. Organizations symbolically bind themselves to one another for all in the environment to see.

With respect to trends toward hierarchy, we are measuring 1) if organizations, which have a number of other organizations already represented on their board, tend to attract more board members from different organizations to their board; and 2) if organizations, which are on several boards already, tend to be represented on even a greater number of organizations over time. One problem here is that organizations can become more "popular" or "expansive," simply because they grow larger over time. Repeatedly, size has been found to be correlated positively with the number of organizational interlocks (see Burt, 1978 and Allen, 1974). In this respect, organizations differ from college students in a fraternity. We suggest that the researcher may want to neutralize organizational size effects by simply choosing to study units both of comparable size and whose sales or assets do not change much over time. A second problem is that financial institutions tend to form more board linkages than non-financial institutions (see Levine, 1972 and Mariolis, 1975). Thus researchers may want to control the number of banks in the network they study as well.

Corporate Interlocks in Minnesota: An Illustration

We chose to examine interlocking corporate directorates among the largest twenty-seven public corporations in Minnesota. Data are for nine years - 1969 to 1977.[4]

Corporations were chosen strictly on the basis of their total sales. Because complete listings of Twin Cities business organizations are not available prior to 1974, we turned to Fortune Magazine's listing of the 1000 largest industrials, 50 largest retailers, 50 largest transportations, 50 largest utilities, 50 largest commercial banks, 50 largest life insurance companies, and 50 largest diversified financial companies. The Fortune listings of the 1000 largest industrials began in 1969. We scanned these lists and identified all business firms located in Minnesota. The Appendix lists the regional firms on these lists for the nine years. Twenty-seven firms were on the Fortune lists for each of the years.

From the annual report of each firm for each of the nine years we were able to identify the board members of each firm and the board members' organizational affiliations. For each year a binary 27 by 27 asymmetric adjacency matrix was constructed. A "1" was placed in a cell (i,j) if some employee of organization j was on the board of corporation i, and a "0" otherwise.

The reader should be aware of two aspects of these data. First, we examine linkages of only a subset of the largest corporations in the area for each year. Unfortunately, there were several organizations not on the Fortune lists for all nine years and we had to drop a corporation from the analysis if it was absent from the Fortune lists for one of the years. Thus we excluded firms which had recently experienced rapid growth or decline (e.g. Tonka), new firms (e.g. Medtronics), privately owned corporations (e.g. Cargill), and firms which previously had been privately owned but are now public corporations (e.g. Donaldson). This exclusion was necessary because of the current lack of stochastic models that allow organizations to enter and leave the system.

Secondly, we examine only the linkages among the 27 "core" firms and ignore board linkages to all other organizations. We analyze approximately 14.5% of the total board linkages of the firms in our network. This is a potential problem.

The organization of a local corporate economy might very well involve smaller units which would be buyers and sellers in the various markets of the larger firms and smaller banks and insurance companies that could provide capital. We suspect that the inclusion of these smaller firms would introduce more differentiation into the system and force the two bank holding companies into the center of the network. Furthermore, by excluding linkages to extra-local firms we are ignoring the obvious fact that most of the "core" corporations are multi-nationals operating in national and world economies. Linkages to "local" firms may be of only secondary importance to them. However, the inclusion of extra-local board linkages would open up a "pandora's box" which would take us well beyond the modest methodological goals of this paper.

Processes of Change for Corporate Networks

In an earlier section we identified two dimensions of macrostructural change in a corporate network, one which focused on reciprocity and the other on dominance or centrality. The dimensions of network reciprocity are reflected in the changes occuring in the dyadic or pair relationships among the organizations. There are $\binom{27}{2} = 351$ dyads in our network. We can categorize the dyad transitional changes into 3×3 matrices, displaying the states of the 351 dyads for every pair of years under investigation. Table 1 gives the dyadic transitions for the 8 pairs of consecutive years 1969-70,...,1976-77.

The second set of dimensions of macro-structural change are of hierarchy. For each of the nine years, we examine the indegree (the number of boards that j is represented on) and outdegree (the number of businesses represented on i's board) process. These correspond to an actor's "popularity" and "expansiveness."[5] The distribution of indegrees is less constant over time than that of the outdegrees. This could mean that there is an informal "quota" of local firms that can be represented on the boards of these corporations, but that the specific local firms may change over time. To best study the outdegree and indegree transitions, we pool the transition matrices for pairs of consecutive years, which effectively increases the sample size from 27 to $8 \times 27 = 216$. Statistically, this pooling of information is justified in the next section, where stochastic models of Wasserman (1978a) are presented to analyze these data. Tables 2 and 3 give the outdegree and indegree transitions from year to year. The entries are the number of firms with out(in)degree i at year t and out(in) degree j at year t+1, where t = 1969,1970,...,1976.

Stochastic Models to Study Structural Change

We have isolated three functions of the Twin Cities corporate network that will allow us to measure the strength of reciprocity and hierarchy formation: dyad process, indegree process, and outdegree process. To determine the effects of reciprocated arcs, popularity, and expansiveness on the probability of linkages forming, we present three stochastic models. These models are based on the continuous time Markov chains presented in Wasserman (1978a, 1979) and Holland and Leinhardt (1977a, 1977b). The models utilized here are discrete time Markov chains, each incorporating four parameters into their respective probability transition matrix that can be analyzed to determine tendencies toward reciprocity or hierarchy. Discrete time versions of these continuous time models avoid the mathematical difficulties that occur when estimating the structural parameters, and appear appropriate for a corporate network since changes in a board of directors occur not continually, but once a year. We now present these models and estimate and interpret the structural parameters in the next section.

Let $\underset{\sim}{X}_t = (X_{ij;t})$ be the adjacency matrix representing the network at time t, where

$$X_{ij;t} = \begin{cases} 1, & \text{if individual from firm } j \text{ is on the board of firm } i \text{ at time } t; \\ 0, & \text{otherwise} \end{cases}$$

We can associate t = 1 with 1969, t = 2 with 1970, ..., and t = 9 with 1977.

Further, let $D_{ij;t} = (X_{ij;t}, X_{ji;t})$ be the dyadic linkage between corporations i and j. A mutual relationship between two corporations is represented as (1,1), a null relationship as (0,0), an asymmetric as either (1,0) or (0,1). We refer the reader to Chapter 2 in Karlin and Taylor (1975) for a review of Markov chain theory.

We let $D_{ij;t}$ be a discrete time Markov chain on the states {(0,0), (0,1) and (1,0), (1,1)} and further assume that $D_{ij;t}$ is statistically independent of all other dyads.[6] Associated with the reciprocity stochastic model is the following probability transition function

$$P_{ij;k\ell}^{t,t+1} = P\{X_{ij;t+1} = \ell | D_{ij;t} = k\}.$$

the probability that the link X_{ij} is either 0 or 1 at time t+1 given that the dyad is in state k, one of the four dyad states, at time t. We also assume that $P_{ij;k\ell}^{t,t+1}$ does not depend on the particular pair (i,j) so that $P_{ij;k\ell}^{t,t+1} \equiv P_{k\ell}^{t,t+1}$ and that these conditional probabilities may be arranged in a (3×3) probability transition matrix $\underset{\sim}{P}_R^{t,t+1}$, shown at the bottom of Table 1.

According to the reciprocity model, the elements of the reciprocity model matrix $\underset{\sim}{P}_R^{t,t+1}$ depend on four parameters λ_0, λ_1, μ_0, μ_1. The theoretical probability transition matrix $\underset{\sim}{P}_R^{t,t+1}$ is a function solely of these four parameters. The parameters λ_0 and λ_1 are measures of the overall rate of change of the network, and μ_0 and μ_1 measure the "importance" of a reciprocated arc. We further discuss these parameters, and functions of them, in the context of our corporate network, in the next section.

Let $I_{j;t} = \sum_{i=1}^{27} X_{ij;t}$, j = 1,2,...,27, and $O_{i;t} = \sum_{j=1}^{27} X_{ij;t}$, i = 1,2,..., 27, be the indegree process for firm j, and the outdegree process for firm i, respectively. We now present the popularity model for the indegree process and the expansiveness model for the outdegree process, both used to study the hierarchical structure of the corporate network. Mathematically, the models are identical ... one need only exchange $O_{i;t}$ for $I_{j;t}$, and the four expansiveness parameters λ_0, λ_1, ε_0, ε_1, for the four popularity parameters λ_0, λ_1, π_0, π_1. Consequently, we present just the popularity model.

The indegree process $I_{j;t}$ represents the number of local firms that individuals from corporation j are represented on at time t. Obviously, $I_{j;t}$ takes on any integer value between 0 and 26, so that $I_{j;t}$ has state space $\{0,1,\ldots,26\}$. We assume that $I_{j;t}$ is statistically independent of the other indegrees, and has probability transition function

$$P^{t,t+1}_{j;k\ell} = P\{I_{j;t+1} = \ell \mid I_{j;t} = k\}.$$

The function for the popularity model specifies the probability that individuals from corporation j sit on the board of ℓ firms at time t+1, given that individuals from j sat on the boards of k firms at time t. We postulate that this function does not depend on the specific corporation j, so that $P^{t,t+1}_{j;k\ell} \equiv P^{t,t+1}_{k\ell}$. We can arrange these probabilities into a (27×27) probability transition matrix $\underset{\sim}{P}^{t,t+1}_{P}$.

In our corporate network, the magnitude of the outdegrees as well as the indegrees reflects the position of the firms in the corporate hierarchy or how "centrally located" they are. In the first case centrality reflects a firm's expansiveness; the second case reflects a firm's popularity. The model postulates that as the position of a firm becomes more important in the network, as its indegree increases, the probability that the indegree $I_{j;t}$ increases by one is a linear function of $I_{j;t}$. Similarly the probability that the indegree decreases by one is another linear function. Thus, popular firms tend to become more or less popular, solidifying the hierarchical structure of the network, as a function of their present popularity.

We postulate that the transition probabilities depend on 4 parameters, λ_0, λ_1, measuring the overall rate of change, and π_0, π_1, measuring the effect of increased centrality on indegree changes, as follows:

$$P\{I_{j;t+1} = i+1 | I_{j;t} = i\} = \lambda_0 + i\,\pi_0$$
$$P\{I_{j;t+1} = i-1 | I_{j;t} = i\} = \lambda_1 + i\,\pi_1$$

for all j, and $i = 0,1,\ldots,26$. The probability transition matrix for the in-degree process, which mathematically is a linear birth-and-death process is a Jacobi matrix, with positive diagonal, sub-diagonal, and super-diagonal, and zeros elsewhere.

Quantification of the Dimensions of Macro-Structural Change

We now apply the stochastic models presented in the previous section to the data on the Twin Cities corporate network of 1969-1977. To estimate the four parameters of each of the three models, we need only compare the theoretical probability transition matrices with the empirical probability transition matrices, constructed from the data in Tables 1, 2, and 3. The empirical probability transition matrices, $\hat{P}_R$, $\hat{P}_E$, $\hat{P}_P$, for the three models, are formed first by pooling the year-to-year transition matrices, and then standardizing by dividing by row sums. This pooling is justified by the assumption that a stationary, first-order Markov chain is operating.

The estimation procedure is discussed in detail in Wasserman (1978a), and will not be presented here. In brief, $\hat{P}$ is "fitted" to P using least squares, minimizing the "distance" between the "observed" and "expected" matrices.

The estimated parameters of the reciprocity model are:

$\hat{\lambda}_0 = .019$ $\qquad\qquad \hat{\lambda}_0 + \hat{\mu}_0 = .015$

$\hat{\lambda}_1 = .111$ $\qquad\qquad \hat{\lambda}_1 + \hat{\mu}_1 = .061$

$\hat{\mu}_0 = -.004$

$\hat{\mu}_1 = -.050$

Looking first at $\hat{\lambda}_0$ and $\hat{\lambda}_1$ we can assess, in the absence of reciprocated links, if asymmetric ties tend to be formed and if asymmetric ties tend to disappear over time. If these trends are present, values for $\hat{\lambda}_0$ and $\hat{\lambda}_1$ will be large. As it turns out, tha rate of asymmetric ties disappearing is greater than the rate of appearing (i.e., $\hat{\lambda}_1 > \hat{\lambda}_0$).

The parameter sums $\hat{\lambda}_0 + \hat{\mu}_0$ and $\hat{\lambda}_1 + \hat{\mu}_1$, tell the the probability of a linkage between actors i and j forming or disappearing given the condition that j is already linked to i. Since $\hat{\lambda}_0 + \hat{\mu}_0$ is equal to .015, we can conclude that the presence of reciprocated arcs has little effect on the formation of subsequent symmetric linkages. That is, asymmetric ties between actors do not tend to become symmetric over time. However, since $\hat{\lambda}_1 + \hat{\mu}_1$ is equal to .061, we can conclude that symmetric linkages do tend to be transformed into asymmetric linkages over time.

The relationship between our parameters is even better understood if we examine estimates of the two reciprocity ratios, ρ_1 and ρ_2:

$$\hat{\rho}_1 = \frac{\hat{\lambda}_0 + \hat{\mu}_0}{\hat{\lambda}_0} = .789 \qquad \hat{\rho}_2 = \frac{\hat{\lambda}_1 + \hat{\mu}_1}{\hat{\lambda}_1} = .550.$$

$\hat{\rho}_2$ tells us that a link is only half as likely to disappear over time in the presence ofareciprocated link than in its absence. Thus; there is a tendency for the integrated network to remain integrated. In contrast $\hat{\rho}_1$ tells us that a reciprocated arc has virtually no impact on linkages from i to j appearing. So while these networks may remain relatively integrated, there is certainly no tendency for the network to "fill up" by asymmetrics becoming mutuals. The log odds ratio log $(\hat{\rho}_1/\hat{\rho}_2) = .157$ is positive however, implying a net, small positive reciprocity effect.

The four expansiveness model parameter estimates are:

$$\hat{\lambda}_0 = .163$$
$$\hat{\lambda}_1 = .003$$
$$\hat{\varepsilon}_0 = -.011$$
$$\hat{\varepsilon}_1 = .048$$

$$\hat{\lambda}_0 + i\hat{\varepsilon}_0 = .163 - .011i$$
$$\hat{\lambda}_1 + i\hat{\varepsilon}_1 = .003 + .048i$$

The interpretations for $\hat{\lambda}_0$ and $\hat{\lambda}_1$ in this model are slightly different than in the previous model. In the reciprocity model $\hat{\lambda}_0$ and $\hat{\lambda}_1$ indicated the rates of change for dyads, contingent upon the absence of reciprocated arcs. In this model $\hat{\lambda}_0$ and $\hat{\lambda}_1$ are rates of change for outdegrees, contingent upon the outdegrees being zero. Since $\hat{\lambda}_0 = .163$, we learn that for firms which have no "core" actors represented on their board there is a tendency for them to recruit firms to their boards over time. As we can see, the rate of change of null times to asymmetric ties is, much greater than the rate of change of asymmetric ties to null ties, as measured by the small values of $\hat{\lambda}_1 = .003$.

The sums $\hat{\lambda}_0 + \hat{\varepsilon}_0 i$ and $\hat{\lambda}_1 + \hat{\varepsilon}_1 i$, respectively, describe the probabilities that, given a certain level of expansiveness, corporations will establish linkages where none had existed and will terminate linkages where some had existed. For example, if $i = 1$, (i.e., one "core" firm on its board) then the probability of a firm recruiting another local firm to its board is .152. In contrast, if $i = 5$, (i.e., five "core" firms) then the probability of a firm recruiting an additional firm is .108. Thus we can conclude that for firms which are less expansive, there is a greater probability that they will recruit another firm in the area (i.e., they may become more expansive). In contrast, for firms which are more expansive, there is a smaller probability that they will recruit more local firms (i.e., they may become less expansive).

On the other hand, if $i = 1$, then the probability of a firm abandoning a linkage where one had existed is .051, which if $i = 5$, then the probability of a firm abandoning a linkage goes to .243. This is significant since it suggests that firms which have serveral local firms on their board are more likely to dismiss firms than firms with fewer local firms on their board. These two processes are definitely working against the formation of hierarchy. In the first case, we discover that firms which are central tend to recruit fewer firms to their boards over time than more peripheral actors. In addition, we further find that more central firms are losing contacts at a greater rate.

The four popularity parameter estimates are:

$\hat{\lambda}_0 = .125$

$\hat{\lambda}_1 = .002$

$\hat{\pi}_0 = .017$

$\hat{\pi}_1 = .050.$

$\hat{\lambda}_0 + i\hat{\pi}_0 = .125 + .017i$

$\hat{\lambda}_1 + i\hat{\pi}_1 = .002 + .050i$

The interpretation of $\hat{\lambda}_0$ and $\hat{\lambda}_1$ for the popularity model is similar to the interpretation of $\hat{\lambda}_0$ and $\hat{\lambda}_1$ for the expansiveness model. Here $\hat{\lambda}_0$ and $\hat{\lambda}_1$ are rates of change for indegrees contingent upon actor j having zero indegrees (i.e., j is not represented on any boards). That $\hat{\lambda}_0$ is equal to .125 suggests that firms which were not on any boards tend to go on boards over time and that $\hat{\lambda}_1$ is equal to .002 suggests that it is very seldom that less popular firms go off boards. Again in this model we see that $\hat{\lambda}_0$ is considerably greater than $\hat{\lambda}_1$.

The parameters, $\hat{\lambda}_0 + \hat{\pi}_0 i$ and $\hat{\lambda}_1 + \hat{\pi}_1 i$ take into account the relative impact of actors' indegrees (or popularity) on their likelihood of going on or going off. The first equation shows that for more popular actors there is a tendency for linkages to be formed where no ties had existed previously. The second shows that for more popular actors there is also a trend to abandon linkages. These popularity findings really do not contradict one another; they simply indicate that the more popular firms tend to go "on and off" boards more frequently than less popular firms.

Conclusions

First, let us briefly review what we found with respect to reciprocity effects. The sum, $\hat{\lambda}_0 + \hat{\mu}_0 = .015$, is the probability that two firms which are already linked by an asymmetric tie will establish a symmetric board interlock between themselves. The sum, $\hat{\lambda}_1 + \hat{\mu}_1 = .061$, is the probability that two firms, which have a mutual linkage, will tend to terminate one of the board linkages. Since $\hat{\lambda}_1 + \hat{\mu}_1 > \hat{\lambda}_0 + \hat{\mu}_0$, we can conclude that over this nine year period it was more common for organizations to turn symmetric ties into asymmetric ties than to convert asymmetric ties to symmetric ties.

The parameters describing tendencies toward hierarchy are a little more difficult to interpret. The parameters sum, $\hat{\lambda}_0 + i\varepsilon_0$, is the probability that a firm will recruit another core firm to its board given that i organizations in the community are on its board already. In Figure 1 we see that the probability of firms establishing more linkages with local actors goes down as the number of local firms on the board goes up. The parameter sum $\hat{\lambda}_1 + i\varepsilon_1$, is the probability that a firm will exclude a local firm from its board given that i organizations are on its board already. In Figure 1 we see that the probability of firms terminating interlocks goes up as the number of organizations on its board goes up. In light of these findings it appears that instead of a hierarchy forming (central actors becoming more central), there are tendencies toward maintaining some balance or equilibrium in the network, preventing any subset of firms from becoming too central in the system.

A second set of parameters also were used to measure tendencies toward hierarchy. The parameter sum, $\hat{\lambda}_0 + i\pi_0$, is the probability that a firm will be represented on another board given that it is already on i boards. In Figure 2 we see that the probability of a firm going on another board goes up as the number of boards that it is on goes up. Finally, the parameter sum, $\hat{\lambda}_1 + i\pi_1$, is the probability that a firm will go off a local board given the number of boards it is on. In Figure 2 we see that the probability of a firm going off a board goes up as the number of boards it is on goes up. These findings may appear to be contradictory; however, given that $\hat{\pi}_1 > \hat{\pi}_0$ we can conclude that there is a greater tendency for "popular" firms to terminate relations as they become more popular than for popular firms to become more popular. This would be consistent with the previous findings indicating that there may be a certain equilibrium that prevents networks from becoming highly centralized or hierarchical.

Needless to say, our efforts are exploratory. Our goal is to demonstrate how the theory of Markov chains can be used to describe certain dimensions of structural change in interorganizational systems. Our specific findings on Minnesota corporate interlocks are difficult to interpret simply because they are the first of their kind. We do not know if in other states symmetric linkages are tending to become more asymmetric indicating perhaps an unraveling of a very dense system. Nor do we know if elsewhere there are tendencies toward equilibrium working against the development of a hierarchically ordered regional corporate network. Similarly, we do not know if the patterns we found for these nine years are comparable to interlock patterns in this state 20 years ago.

Given the various problems with our data that we discussed earlier, we offer our specific analyses as a model for future research only with great reservation. However, we do believe that that application of stochastic models to the analysis of interorganizational networks does have a great deal of promise. By applying these models to corporate boards, we have been able to describe basic, substantively meaningful structural changes in the network as a whole. Obviously, the next step is to explain why the changes take place. Our hope is that this research note stimulates the curiosity of organizational researchers and hastens the development of theory and appropriate methodologies for the study of interorganizational systemic change.

APPENDIX: Twin Cities' Corporations on *Fortune's* Lists of Top Earning U.S. Corporations.

	1969	1970	1971	1972	1973	1974	1975	1976	1977
INDUSTRIALS									
American Crystal[7]	x	x	x	x	x	x	x	x	x
American Hoist & Derrick	x	x	x	x	x	x	x	x	x
Apache	x	x	x	x	x	x	x	x	x
Artic Enterprises				x	x				
Bemis	x	x	x	x	x	x	x	x	x
Control Data	x	x	x	x	x	x	x	x	x
Data 100							x	x	x
DeLuxe Check Printers	x	x	x	x	x	x	x	x	x
Donaldson Co.						x	x	x	x
Economics Lab	x	x	x	x	x	x	x	x	x
Farmers' Union Exchange	x	x	x	x	x				
General Mills	x	x	x	x	x	x	x	x	x
George Hormel	x	x	x	x	x	x	x	x	x
Green Giant	x	x	x	x	x	x	x	x	x
Fingerhut		x		x	x				
H. B. Fuller				x	x		x	x	x
Hoerner Waldorf[8]	x	x	x	x	x	x	x	x	
Honeywell	x	x	x	x	x	x	x	x	x
International Multifoods	x	x	x	x	x	x	x	x	x
Jostens	x	x	x	x	x	x	x	x	x
Land O'Lakes[9]	x	x	x	x	x	x	x	x	x
McQuay Perfex			x	x	x	x	x	x	x
MEJ									x
Medtronics							x	x	x
Midwest Cooperatives	x	x	x	x		x	x	x	x
Northrup King	x	x							
Minn. Mining & Manufacturing	x	x	x	x	x	x	x	x	x
Munsingwear	x	x	x	x	x	x	x	x	x
Peavey				x	x	x	x	x	x
Pillsbury	x	x	x	x	x	x	x	x	x
Tonka					x	x	x		
Toro	x	x	x	x	x	x	x	x	x
COMMERCIAL BANKING COMPANIES									
First Bank System	x	x	x	x	x	x	x	x	x
Northwest BANCO	x	x	x	x	x	x	x	x	x
RETAILING COMPANIES									
Dayton-Hudson	x	x	x	x	x	x	x	x	x
Gamble-Skogmo	x	x	x	x	x	x	x	x	x
TRANSPORTATIONS									
Burlington-Northern	x	x	x	x	x	x	x	x	x
North Central		x	x	x	x	x	x	x	x
Northwest Orient	x	x	x	x	x	x	x	x	x
Soo Line	x	x	x	x	x	x	x	x	x
UTILITIES									
NSP	x	x	x	x	x	x	x	x	x
LIFE INSURANCE COMPANIES									
Minnesota Mutual	x	x	x	x	x	x	x	x	x
Northwestern National	x	x	x	x	x	x	x	x	x
DIVERSIFIED FINANCIAL COMPANIES									
IDS			x	x	x	x	x	x	x
St. Paul Companies			x	x	x	x	x	x	x

FOOTNOTES

1. For a review of the recent literature on interorganizational relations and a description of the theoretical and methodological problems involved in the study of these networks, see Laumann, Galaskiewicz, and Marsden (1978) and Aldrich (1979).

2. We suspect that the research of population ecologists on selective environmental mechanisms holds the most promise (see Hannan and Freeman, 1977). Yet the focus in this literature has been on the composition of the organizational population with no attention given to the network structures among organizations.

3. Several authors have suggested that an organization's centrality in an interorganizational network is an indicator of its dominance. See Galaskiewicz (1979) for a summary discussion of these issues.

4. The reasons for choosing this type of interorganizational system are: 1) the organizations in the network are directly comparable, 2) this type of interorganizational linkage is more easily interpretable than others, 3) the number of linkages that organizations can sustain is fairly constant over time, i.e., organizations tend to have the same number of board members over extended periods of time, 4) there has been very little change in the composition of the population of organizations over this nine year period, 5) recent work by Mariolis (1975) and Allen (1978) suggest that regional corporate interlock networks are meaningful economic subsystems in their own right, and 6) the data were readily available.

5. For the time being, we will use the notions of an organization's popularity and expansiveness. These characterizations of indegree and outdegree processes are taken from the literature on friendship systems. Individuals who receive many choices as friends are "popular" while those who say they have many friends are "expansive." For corporate interlocks the substantive meaning of indegrees and outdegrees is somewhat similar. An organization which is represented on many outside boards is "popular" while an organization which allows many local firms on its board is "expansive."

6. See Wasserman (1978a) for comments on the assumption.

7. American Crystal only moved to Minnesota in 1974 from Denver. For this reason it was not included in our sample of organizations.

8. On February 22, 1977, Hoerner Waldorf merged with Champion International. Despite this, Hoerner Waldorf was included in our sample.

9. Land O'Lakes is a cooperative and an inspection of its board showed that all members are dairy farmers. Because of the uniqueness of this organization, it was excluded from our analysis.

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TABLE 1. Dyadic Transitions for Every Pair of Consecutive Years, and Theoretical Probability Transition Matrix for the Reciprocity Model.

N = null dyad; A = asymmetric dyad; M = mutual dyad.

1969 → 1970	N	A	M	Total
N	301	7	0	308
A	2	35	2	39
M	0	0	4	4
Total	303	42	6	

1970 → 1971	N	A	M	Total
N	295	8	0	303
A	4	38	0	42
M	0	0	6	6
Total	299	46	6	

1971 → 1972	N	A	M	Total
N	294	5	0	299
A	5	41	0	46
M	0	0	6	6
Total	299	46	6	

1972 → 1973	N	A	M	Total
N	205	5	0	299
A	5	41	0	46
M	0	0	6	6
Total	299	46	6	

1973 → 1974	N	A	M	Total
N	297	2	0	299
A	4	42	0	46
M	0	0	6	6
Total	301	44	6	

1974 → 1975	N	A	M	Total
N	296	5	0	301
A	9	35	0	44
M	0	0	6	6
Total	305	40	6	

1975 → 1976	N	A	M	Total
N	300	5	0	305
A	6	33	1	40
M	0	1	5	6
Total	306	39	6	

1976 → 1977	N	A	M	Total
N	298	8	0	306
A	3	34	2	39
M	0	2	4	6
Total	301	44	6	

$P_R^{t,t+1}$:

	N	A	M
N	$1-2\lambda_0$	$2\lambda_0$	0
A	λ_1	$1-(\lambda_0+\lambda_1+\mu_0)$	$\lambda_0+\mu_0$
M	0	$2(\lambda_1+\mu_1)$	$1-2(\lambda_1+\mu_1)$

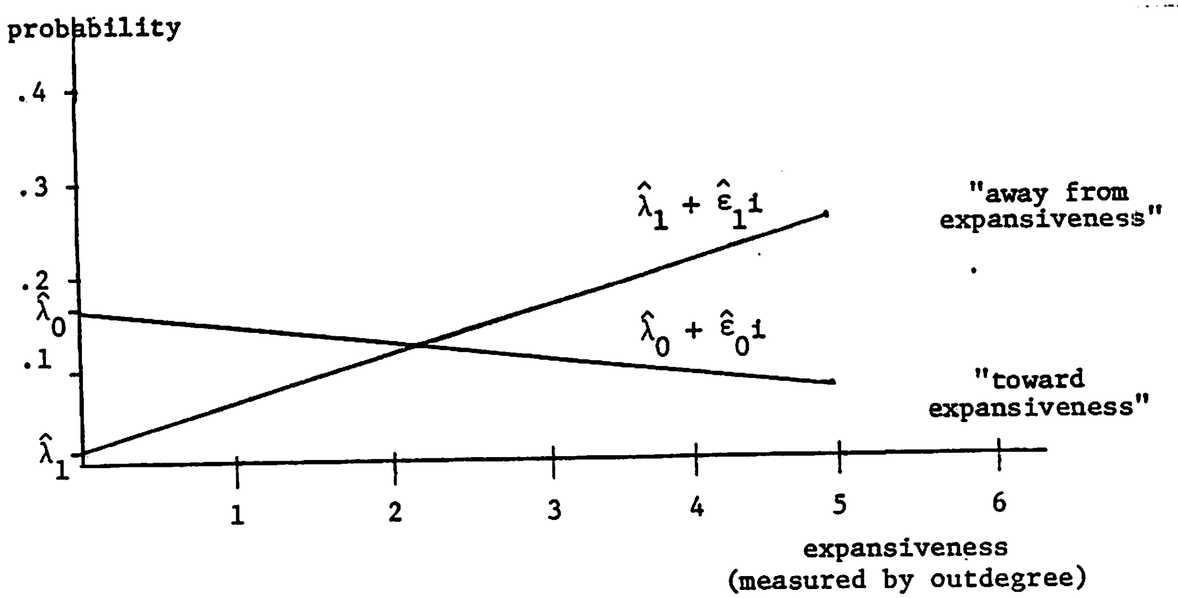
TABLE 2. Outdegree Transitions from year t to year t+1, for t = 1969, 1970, ..., 1976.

Year t \ Year t+1	0	1	2	3	4	5	6	7	8	9	10	
0	59	9										68
1	4	40	2	1								47
2		1	20	9								30
3		1	6	22	4	1						34
4				4	4	2						10
5					2	6	1	1				10
6						1	1					2
7							1	2		1		4
8								2	3			5
9								1	1	2	1	5
10										1		1

TABLE 3. Indegree Transitions from year t to year t+1, for t = 1969, 1970, ..., 1976.

Year t \ Year t+1	0	1	2	3	4	5	6	7	8	9	10	
0	37	9	3									49
1	6	53	6	1								66
2	2	6	28	3								39
3			1	23	4							28
4				2	8	2	1					13
5					2	4	1					7
6								1				1
7						1						1
8								1	1	2		4
9							1		2	2	1	6
10										1	1	2

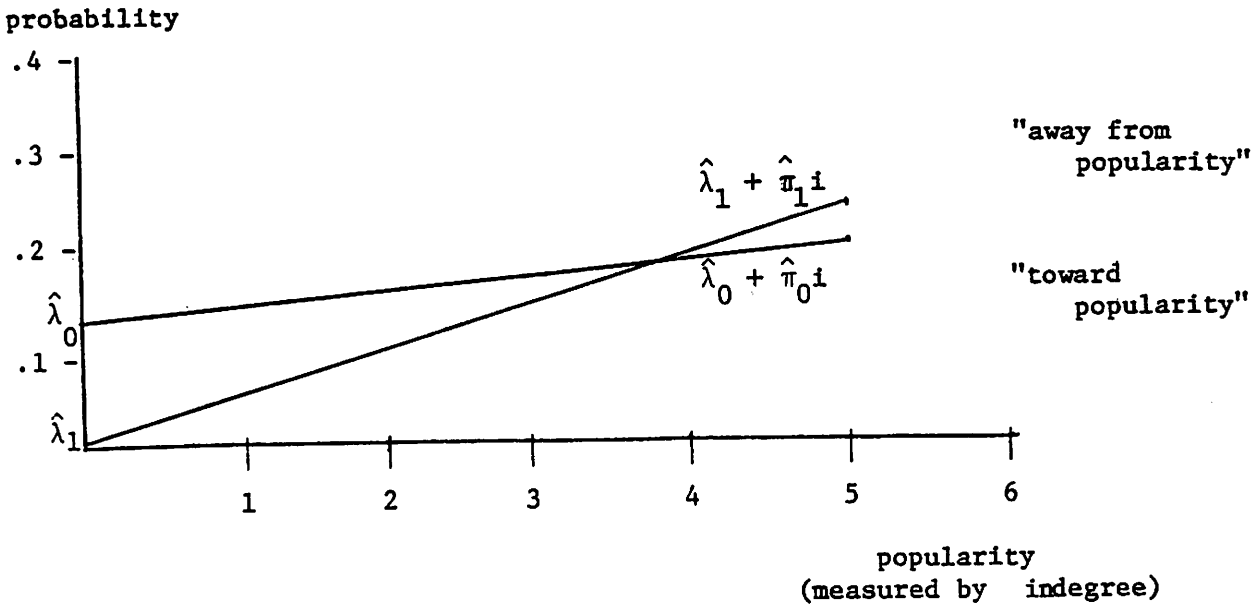
FIGURE 1. Expansiveness Model Transition Rates



$$\hat{\lambda}_0 + \hat{\varepsilon}_0 i = .163 - .011i$$

$$\hat{\lambda}_1 + \hat{\varepsilon}_1 i = .003 + .048i$$

FIGURE 2. Popularity Model Transition Rates



$$\hat{\lambda}_0 + \hat{\pi}_0 i = .125 + .071i$$

$$\hat{\lambda}_1 + \hat{\pi}_1 i = .002 + .050i$$