Evolution on a Dancing Landscape: Organizations and Networks in Dynamic Blau Space*

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Abstract

This article develops and tests an evolutionary model of the growth, decline, and demographic dynamics of voluntary organizations. The model demonstrates a strong analogy between the adaptive landscape of Sewall Wright (1931) and the exploitation surfaces generated by a model of member selection and retention for voluntary associations. The article connects the processes of membership recruitment and loss to the social networks connecting individuals. The model generates dynamic hypotheses about the time path of organizations in sociodemographic dimensions. A key idea in this model is that membership selection processes at the individual level produce adaptation in communities of organizations. The article concludes with an empirical example and some discussion of the implications of the model for a variety of research literatures.

Predicting the behavior of empirical systems has proven to be an elusive goal for the social sciences. This article outlines a theory that predicts the growth, decline, and demographic changes of social groups. The theory posits a Darwinian mechanism of systematic variation, selection, and retention of members in groups. Social network theory provides a framework for understanding how social evolution (the transitions from hunting and gathering societies through the intervening stages to the contemporary industrial stage) has created the conditions for the Darwinian mechanism of the model. This study takes a brief tour through the macroevolutionary foundations of the theory to set the stage for the microevolutionary test of the model. The predictions tested in the article are in the short term — over a period of less

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than two decades. However, the mechanism of the model could in principle account for changes in the very long term.

The core idea of the evolutionary model is that social groups exist in a multidimensional space of sociodemographic dimensions best identified with the work of Peter Blau, particularly his *Inequality and Heterogeneity* (1977). Since our interpretation of Blau is somewhat novel, we will try to distinguish clearly those occasions when we are adding to Blau from those when we are borrowing. We use voluntary associations (Knoke 1990; Smith & Freedman 1972) to illustrate the theory. These groups are a very interesting case for our theory because the entry and exit of the members are least constrained by macroinstitutional structures such as law and economy in late industrial societies.

The Origins of Blau Space

The received view[1] of the early stages of human social evolution is that people existed in small hunter-gatherer social systems for tens of thousands of years (cf. Lenski & Lenski 1970). These groups were geographically mobile bands of ten to fifty individuals engaged in face-to-face everyday contact (cf. Sahlins 1972). The adult men appear to have hunted small game, while adult women and children gathered fruits, berries, and other vegetable material; the division of labor was based largely on age and sex. All social contact in such small systems was multiplex in that all connections among the people in the community had multiple components; they were simultaneously based on kinship, acquaintanceship, exchange, sustenance, sociality, and all other relations necessary to the survival of a small society (cf. Mauss 1966).

As societies increased in scale, these small multiplex social networks differentiated into separate simplex networks spanning more people. In hunting and gathering societies, almost all social contacts had multiple facets; contacts were based on simultaneous multiple connections. Most people saw each other face to face, engaged in exchange relations, and were kin to one another. The increase in the size of society broke down the multiplex relations into their constituent (simplex) elements as they were spread over larger and larger numbers of contacts. As the division of labor became more developed, the bases of social relations became more diverse. The face-to-face power relationships of the band of twenty to fifty people who spent all their lives together slowly evolved into anonymous bureaucratic systems based on universalistic criteria. The day-to-day repetition of identical tasks involving the same communications with the same individuals were replaced by an ever increasing diversity of activities involving social networks of communication, exchange, migration, and acquaintanceship.

Most of the major figures in sociological theory have a version of this transition. For instance, Durkheim (1933) spoke of the change in dynamic density because of the shift from mechanical to organic solidarity, while Toennies ([1887] 1940) thought in terms of the transition from gemeinschaft to gesellschaft. Likewise, Simmel (1950) argued that increases in system size qualitatively changed the web of connections between individuals. Weber's interpretation (1947) of the growth of bureaucratic systems is sociological dogma. As Blau (1989) has indicated, the original objective of sociology was to understand the interdependence of these characteristics of society.

The most important consequence of the change from the primal dense multiplex networks to sparse simplex nets based on increasingly specialized interactions is that the separation of the relations into their constituent parts produces dimensions of social life in which the management of social diversity becomes problematic for society. When power relations must span systems of millions of people, the bases of those relationships must become standardized and universalized. We no longer respond to each other as people with whom we share unique long-term experiences but as people with a given level of education, wealth, or occupational prestige. Thus, social order that depends on the unique history of interaction between small numbers of people in isolated bands is replaced by social order based on generalized dimensions of social esteem, rank, and sociodemographic characteristics.[2]

Blau (1977, 1989) used this idea to explore the proposition that the relations among individuals in modern industrial societies are shaped by properties of this space of sociodemographic dimensions. When the dimensions are strongly correlated, social relationships are constrained; one will not encounter women who are highly educated or grade school dropouts with large incomes. When the dimensions are less correlated, society is more diverse; one cannot predict one set of social characteristics from another. Thus, the correlations among the dimensions are essentially related to the number of them. When *K* dimensions are perfectly correlated, they operate as one. When *K* dimensions are uncorrelated, each dimension allows social differentiation along a new axis. What Blau leaves implicit in his theory is that the long run of history — the transition from hunting and gathering to industrial modes of production — is the transition from strong correlations in a limited number of dimensions to weaker and weaker correlations among an increasing number of these dimensions (but see Blau 1989). As multiplex relations based on small intensely focused groups give way to specialized relations spanning larger and larger systems, the proliferation of these specialized relations generates Blau space — the dimensions in which social differentiation occurs (see also Redfield 1947, Schnore 1958, Smith [1776] 1971, and Spencer 1899).

Organizations and Individuals in Blau Space

A way of thinking about Blau's property space is that each individual occupies a point in a multidimensional coordinate system defined by the Blau variables such as education, age, and occupational prestige. The configuration of these points in Blau space determines the correlation of the dimensions at the system level. When the variables are strongly correlated, there are constraints on the distribution of points in the space; if occupational prestige and educational attainment are strongly related (cf. Blau & Duncan 1967), then most people in the system will be near the line of regression. When the variables are weakly correlated, the points are scattered in the space, and there is more room for social differentiation. As society increases in size and scale, multiple dimensions for ranking individuals come into being, and these multiple dimensions become less and less correlated over time. The increasing number of outliers in the system (the individuals whose values on one Blau dimension are not consistent with their values on another) become identifiable social categories, with distinctive life chances and institutional structures.

Social network researchers have long known that contacts between individuals in this space are not random. The probability of contact between two people is a declining function of distance in Blau space. This result occurs because the networks are homophilous; that is, the probability that two individuals are connected to each other in the network of social contacts (e.g. kinship, friendship, acquaintanceship) depends on their similarity (cf. McPherson & Smith-Louis 1982, 1987; Marsden 1987). Since similarity is an inverse function of the distance between the two individuals on any given Blau dimension (e.g., the farther apart two people are in years of education, the less similar they are), the distance between two points in Blau space determines the probability that the two points are connected.[3] Homophily vastly reduces the complexity of the network by translating the *N* individuals with *R* possible types of relationships into *N* individuals with *K* values on metric dimensions.[4]

The powerful idea in this model is that the connections that do *not* exist determine how the system behaves. These networks are always very sparse for communities larger than a few hundred. Given the finite capacity for human interaction, points in the network will be connected to only a very small proportion of the others in a large system; given homophily, most of the points connected will be close to each other in Blau space. Thus, processes such as the passage of information through large social networks are more determined by the absence of connections between individuals than by the presence of them.[5] Homophily becomes more important in determining transactions in the system as the size of the network increases. As we will see, the formation of voluntary groups depends on this fact.

Since the networks are homophilous, activities that involve the mobilization of multiple individuals through the network will tend to be localized, since it is only locally that the network is dense enough to sustain the coordination of many individuals.[6] This localization of activities explains why organizations formed through social networks develop distinctive niches in Blau space (McPherson 1983).[7] This effect is heightened because the internal processes of these organizations are often dependent upon "sociation," which is facilitated by similarity among the members and hindered by heterogeneity (McPherson & Smith-Lovin 1986, 1987).

Membership Growth and Decline as Natural Selection

The recruitment of new members to organizations is conservative because the group replicates itself through homophilous connections. The group tends to stay in the same region of Blau space because the current members have connections primarily to people nearby in Blau space. If recruitment to a group depends on contact with more than one member, the conservative effect will be enhanced. When multiple contacts with members increase the probability of joining a group, then potential members nearer the center of the group niche are differentially selected; only in the interior of the group's niche are multiple contacts likely. Homophilous recruitment stabilizes the group in its current position in Blau space.

This version of social dynamics is a classical Darwinian model of variation, selection, and retention (Darwin [1859] 1964). The population of individuals at risk for membership varies in the characteristics defined by the Blau dimensions. When potential members become actual members, their characteristics become the basis for the selection of further members. The stability of the membership pool in Blau space is shaped by homophily in the social network as an analogy to the genetic stability of populations of organisms in biotic communities. The fact that the replication of characteristics is not exact does not destroy the analogy. The stochastic nature of the selection process is balanced by the conservatism of the recruitment process. Each generation of members recruits similar new members through the constraints imposed by homophily in the social network.

At the organizational level, the distribution of the individual characteristics is analogous to the distribution of genes in a biotic population. Organizations maintaining their niche recruit new members like themselves, just as stable biological populations produce the same distribution of genes from generation to generation. Normal processes of recruitment and attrition will result in stable niches through homophilous selection processes. When the population of members (the group) expands or contracts its niche space, it does so by recruiting or losing members at the edges of the niche. New members who are significantly different from the old are like mutations whose viability is being tested. If the new mutation survives (i.e., if the dissimilar member is retained), the group adapts in the direction of the new member whose connections to new potential members can generate more new members similar to the latest. If the new mutation dies (i.e., if the novel member leaves the group), the group maintains its old niche. Thus, selection of members produces adaptation (change in the position of the group) in Blau space.

Competitive Dynamics

The group replicates itself over time through the selection mechanism. When the system is in equilibrium, each group will stay in its niche, and the niches will be distributed regularly through Blau space by the competition of groups for the time and for other resources of the individuals. When two groups are located in the same niche, their attempts to consume the resources of the same people leads to competitive exclusion over time (Gause 1934). The resources of the individuals in the community are finite; when an increasing demand is made upon these resources by groups occupying the same niche, one or the other group will be excluded over time (Popielarz & McPherson 1991). As these forces equilibrate, the groups adjust to each other in the space. When a group is in a region not hotly contested by other groups, potential members in that region will join at a higher rate, and current members will stay longer. When a group is located in a densely occupied region, potential members will be less likely to join, and current members will be more likely to leave. The distribution of group members across the Blau dimensions responds over time to the differential competitive pressures presented by other groups.

The competitive pressures can vary in their effects on different parts of a group's niche. Groups facing increasing competitive pressure on all edges in Blau space will contract in Blau space as their peripheral members are lost to other groups. The one-to-one correspondence between volume in Blau space and membership diversity means that the group will grow less and less diverse as it shrinks in volume. If the group does not increase the density of its membership in the shrinking region of niche space, it will lose members.

On the other hand, a group facing great competitive pressure in one direction of Blau space and less in the other direction will move through the space as it picks up members in one direction and loses them in the other. A group with reduced competitive pressures in all directions will expand its volume and become a generalist. Thus, differential competition can account for the location of groups in Blau space, their volume in that space, and their growth or decline in numbers. The next section explores circumstances leading to such differentials.

The Carrying Capacity

The potential of the pool of individuals in a given region of Blau space to support group activity is the *carrying capacity*. The system of organizations approximates the carrying capacity over time through the mechanisms of selection and competition. When a region of Blau space has few groups, it is underexploited, and the mechanism of the previous paragraph will lead to invasion by neighboring groups or the formation of new groups. When a region is overexploited, the carrying capacity will be exceeded, and groups will tend to move away from that region or decline in membership.

The carrying capacity for groups is greater in some regions of Blau space than in others for several reasons. First, the number of individuals varies from region to region; Blau's *Inequality and Heterogeneity* (1977) explores the consequences of this fact. When dimensions are correlated, individuals are crowded into limited areas of the space, while other areas are vacant. For example, people will be clustered closely about the regression line relating education and occupational prestige when these dimensions are strongly related. This clustering reduces the available area in Blau space for organizations to exist; groups must be tightly packed around the regression line. Lower correlations allow groups to move farther and farther away from the line, as more people are dispersed. In the extreme case, two perfectly correlated dimensions are effectively reduced to one. On the other hand, when two dimensions are perfectly uncorrelated, people are maximally dispersed through the niche space, and group activity can occur at any location. Thus, the correlation between Blau dimensions affects the carrying capacity for groups in different areas of the space.

A second reason for variation in the carrying capacity in Blau space is that the density of connections between people varies systematically. It is known that the number and range of social contacts varies with social class, age, and other sociodemographic characteristics (cf. Marsden 1987). Since these contacts form the channels through which the organization propagates itself, higher density of contacts in a local region facilitates group formation and persistence. When connections between people are sparse, groups recruiting through these links will have difficulty acquiring new members. At the limit, no matter how many people are in a region, organizations cannot form if there are no connections between individuals.

Finally, other competitors for the time and other resources of the people in the region will set limits to the ability to sustain group activity. For instance, certain types of occupations (e.g., forest ranger) will interfere with voluntary group membership, while others will facilitate it (e.g., politician). Large families in low social status regions may consume more time that would otherwise be available for voluntary group activities than the smaller families of higher status individuals. The correlation between the average number of memberships and variables such as education, age, and income has been well established for decades (Babchuk & Edwards 1969, Bell & Force 1956; Lundberg, Komarovsky & McInery 1934; see review in Smith 1975). The carrying capacity of our model is a multidimensional interpretation of this well-known correlation.[8]

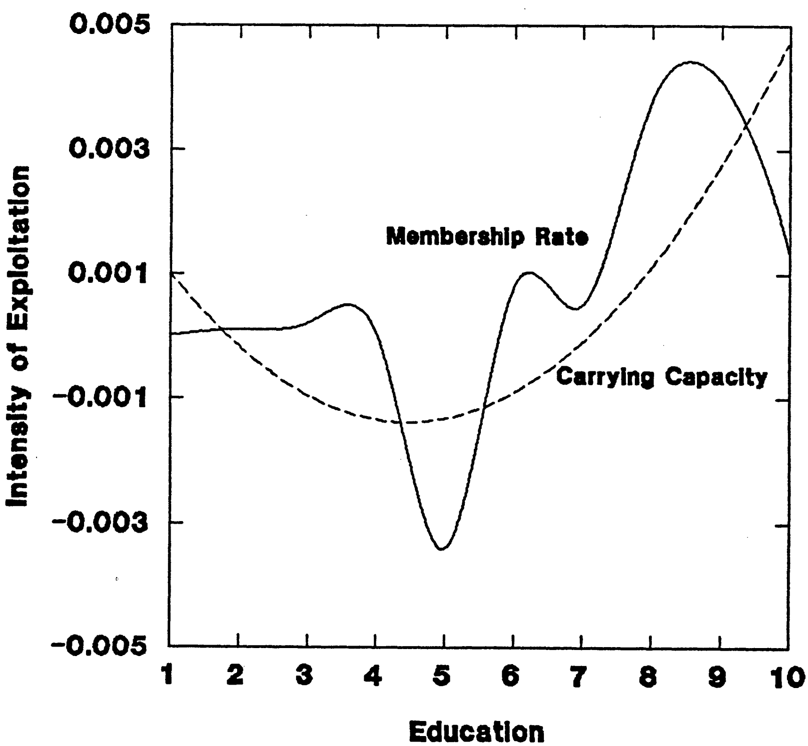
DYNAMICS OF EXPLOITATION

The exploitation rate at any given time varies around the carrying capacity; perturbations and stochastic events produce short-term increases and decreases in the number of organizational memberships. Transient fluctuations above the carrying capacity will be brought back down by the greater competitive pressures in the overexploited region, while momentary dips below will be corrected by the increased rate of joining and retention of members in that region. These dynamics are illustrated in Figure 1. The carrying capacity, the dashed line, is the underlying rate at which the population of individuals can sustain organizational activity in the long term. The deviations from this underlying carrying capacity in the short term (the membership rate in cross section) produces effects on the gain and loss of members, effects that can be used to test the model.

These deviations form an opportunity space for the organizations; their membership composition responds to a local excess of memberships as the rate of joining decreases and the rate of leaving increases. The net effect is for groups to move away from overexploited regions and to move toward underexploited regions. These dynamics are demonstrated in Figure 2, a hypothetical exploitation surface. The exploitation surface is the difference between the carrying capacity and the short-term rate of group membership — the difference between the dashed and solid lines of Figure 1.

This exploitation surface represents the gradient of high and low opportunity for the organizations in Blau space. Groups will move toward regions of underexploitation — the valleys in the surface — and away from regions of overexploitation — the peaks in the surface. For instance, group A is located on a regular incline with greater opportunities located at higher levels of education. The group will lose more and gain fewer members in the low-education direction, while gaining more and losing fewer in the high-education direction.

FIGURE 1: Carrying Capacity and Membership Rate in One-Dimensional Blau Space

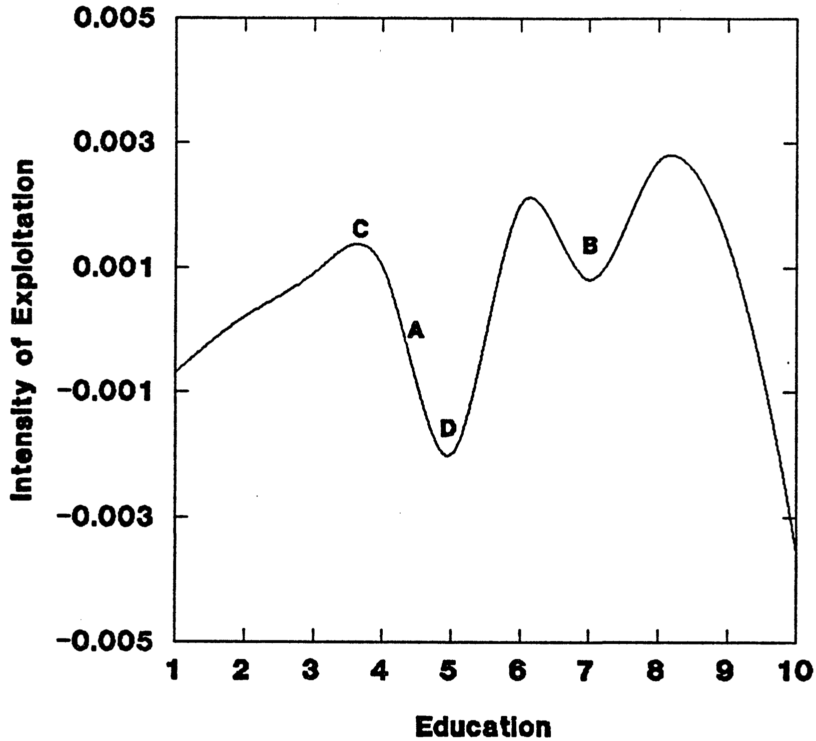


The net result will be a shift in the composition of the group toward higher education.

Group B, on the other hand, is trapped in a region of high exploitation by the steep walls of the function at the edges of the group's niche and will be unlikely to escape to a more favorable region. Under the model, this group will decline in size and may shrink in volume since it is unable to climb the walls of the trap to recruit members from regions of lower exploitation. Group C is located in an overexploited region but can move in the space. It may move either to higher or lower levels of education, or both. Pressures will force the group to generalize in the education dimension by recruiting differentially at the edges of the niche. If these pressures persist over a sufficiently long period, the group will develop a bimodal distribution of members. The resulting cleavage in the internal demography can lead to splitting of the group into two distinct groups, internal conflict, internal structural differentiation, or other theoretically interesting outcomes.

Group D will grow in size, being located in a favorable region for membership affiliation and retention, and may generalize in the space as well, since

FIGURE 2: Hypothetical Organizations on a One-Dimensional Exploitation Surface



opportunities exist at the edges of the niche. On the other hand, if group D's curve were located higher, near 0 on the y-axis, we would predict stability for group D's membership. The vertical axis, then, governs the ratio of acquisition to loss of memberships under the model. The groups high in the exploitation dimension will lose more members than they gain, while groups in the lower region will gain more than they lose. The local shape of the exploitation curve governs the direction of adaptation of the group. The selection and retention processes at the membership level produce adaptation of the group in Blau space.

The generalization of this exploitation curve to multiple dimensions generates an adaptive landscape reminiscent of the evolutionary theories of Wright (1931). The imagery that Wright used was that species adapt in a landscape where the y-axis describes the fitness of the species. Individual members of the species had differential survival rates depending on their position on the fitness gradient. The population moved in the fitness space to local maxima, and the system stabilized when all species were at local maxima.

A significant difference between Wright's adaptive landscape and ours is that this gradient surface dances (Kauffman 1988). That is, the surface is affected directly by the movement of the group upon it. When a group enters a region of the exploitation surface, it adds its members to the pool of members already in that region, altering the height of the exploitation curve. In the long run, the exploitation curve will tend toward a straight line of zero slope, since it represents the transients from the carrying capacity curve. The movements of the exploitation curve are produced by the movements of groups in the aggregate, responding to the local shape of the exploitation function.

We emphasize that the exploitation curve is a transient phenomenon. The model posits that the local deviations from the carrying capacity will tend to return to equilibrium over time, as the groups floating on the dancing landscape adjust their locations. The transients may come from several sources. First, they may be produced by short-term demographic changes. Large migration events such as the influx of new people into the system through the opening of a new plant or transportation system can perturb the system. The age structure of the population of individuals may be shifting quickly, as in the case of the baby-boom bulge moving through the demographic structure. These transient events will produce perturbations in the community of organizations as they work toward a new short term equilibrium. The introduction of a new large organization from outside the system can force adjustments in the community of organizations.

Large-scale transient events such as wars, economic dislocations, and social movements may also produce perturbations in the system. The deletion of large numbers from the pool of potential members of social groups — through an increase in the female labor force, for instance — will be equilibrated over time by a reduction in the carrying capacity in one region of Blau space and a possible increase in the capacity for, perhaps, union or professional membership in another region of occupational prestige. This abrupt shift in the underlying carrying capacity will perturb the interdependent organizations floating on this surface in waves that will take longer to dampen out. In addition, there may be inherent stochastic properties of the system that produce variation over time from equilibrium. Components of the system may be chaotic (Gleick 1987, May 1987) leading to continuous deviation from the equilibrium under the model.

The basic argument, then, is that organizations will respond to perturbations from the carrying capacity of Figure 1. An opportunity appears near an organization when there is a transient deflection downward in the exploitation curve. This opportunity is a region in the adaptive landscape that is temporarily underexploited. Nearby organizations will find it easier to recruit members in this region; current members in this region will have less pressure on their time and other resources. Thus, the organization will move in the direction of this temporary opportunity as more members are recruited from this direction and as fewer members are lost.

Before leaving the dynamics of the system under the model, we want to discuss briefly some other views of organizations. In institutional analysis, the emphasis is on the rules and "taken-for-granted" character governing the activities of the group (Dimaggio & Powell 1983; Meyer & Rowan 1977). These institutional forces act as a drag on the movement of the group in Blau space in the sense that the major thrust of institutional forces is to stabilize, regularize, and normalize activity (Scott 1988). These forces are essentially the null hypothesis for the model; they provide another theoretical interpretation for nonmovement in Blau space. If the evolutionary model successfully describes movement in the system, the explanation that groups are the way they are because their rules tell them to be that way gives way to the Darwinian argument that groups are the way that they are because the environment has selected them to be that way. On the other hand, if there is no movement in Blau space, or if such movement is random, we must reject our evolutionary view in favor of the conventional institutional view.[9]

The evolutionary model can also be contrasted with rational-choice theory (Hechter 1987). The evolutionary model is explicitly nonstrategic, in the sense that there is no argument here that group leaders or members are making decisions or choices about member recruitment or that individual choices have any systematic effect at all. The premise is that people cannot join groups that they never contact; most groups are so distant from us in Blau space that we never have any opportunity to join them. We do not need to know why a member thinks s/he joined the group; any individual's interpretation of that event is limited to the information available in that restricted region of Blau space. We believe that the macrosocial process can only be understood by outlining the limits of behavior, rather than outlining what item of behavior the individual chooses to exhibit from the limited menu available. As we have argued from the outset, this limitation increases in power as time brings larger and larger systems into being.

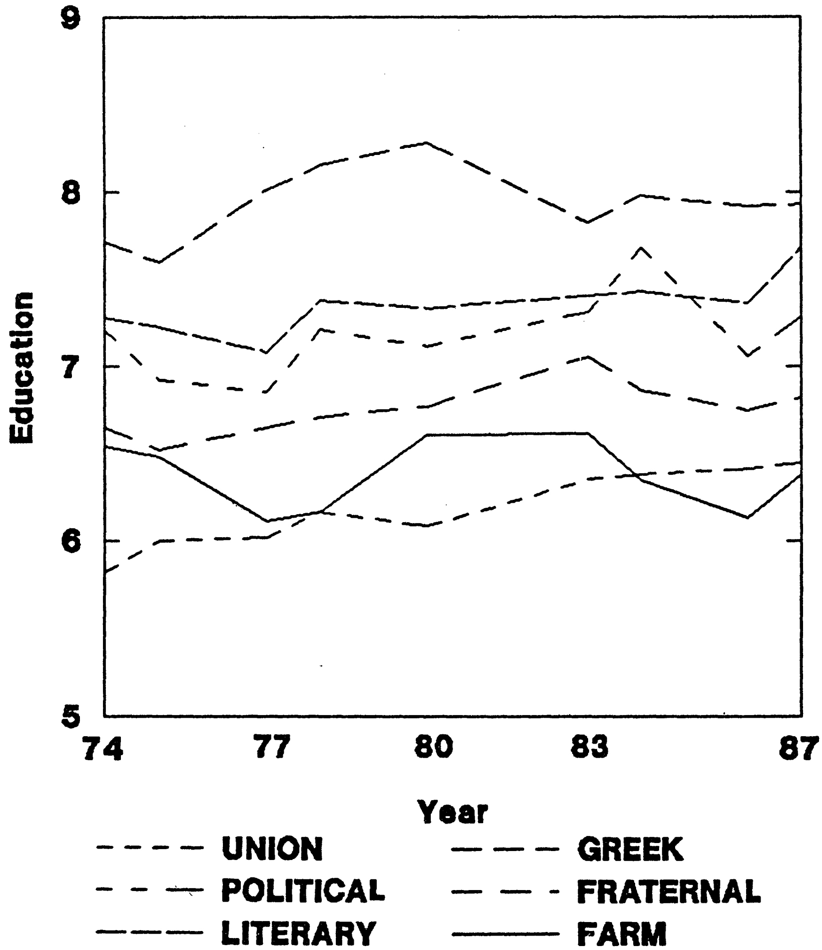
Data and Methods

The only data currently available on voluntary affiliation over time with enough statistical power to test predictions from the model come from the voluntary association affiliation module of the General Social Survey (GSS). The voluntary affiliation questions were collected in the years 1974, 1975, 1977, 1978, 1980, 1983, 1984, 1986, and 1987 (Davis & Smith 1988). The respondents were asked to report on their memberships in each of sixteen types[10] of voluntary associations. Since the GSS does not collect information on specific organizations, but only types of organizations, we will be limited to hypotheses about the niche behavior of organizational types, rather than specific organizations, following the strategy of McPherson (1983). In addition, since the GSS is a trend study, we cannot track individuals over time; we must confine our attention to the behavior of individuals aggregated in Blau space.

What this means is that we cannot test ideas about specialization and generalization of organizations in Blau space, nor can we detect group formation or dissolution. We will be able to examine only shifts in the niches of populations of organizations operating in the aggregate, instead of concrete organizations in identifiable communities. While this limitation is serious, there is evidence to suggest that organizational niches can be detected at these higher levels of aggregation (cf. McPherson 1983, McPherson & Smith-Lovin 1988).

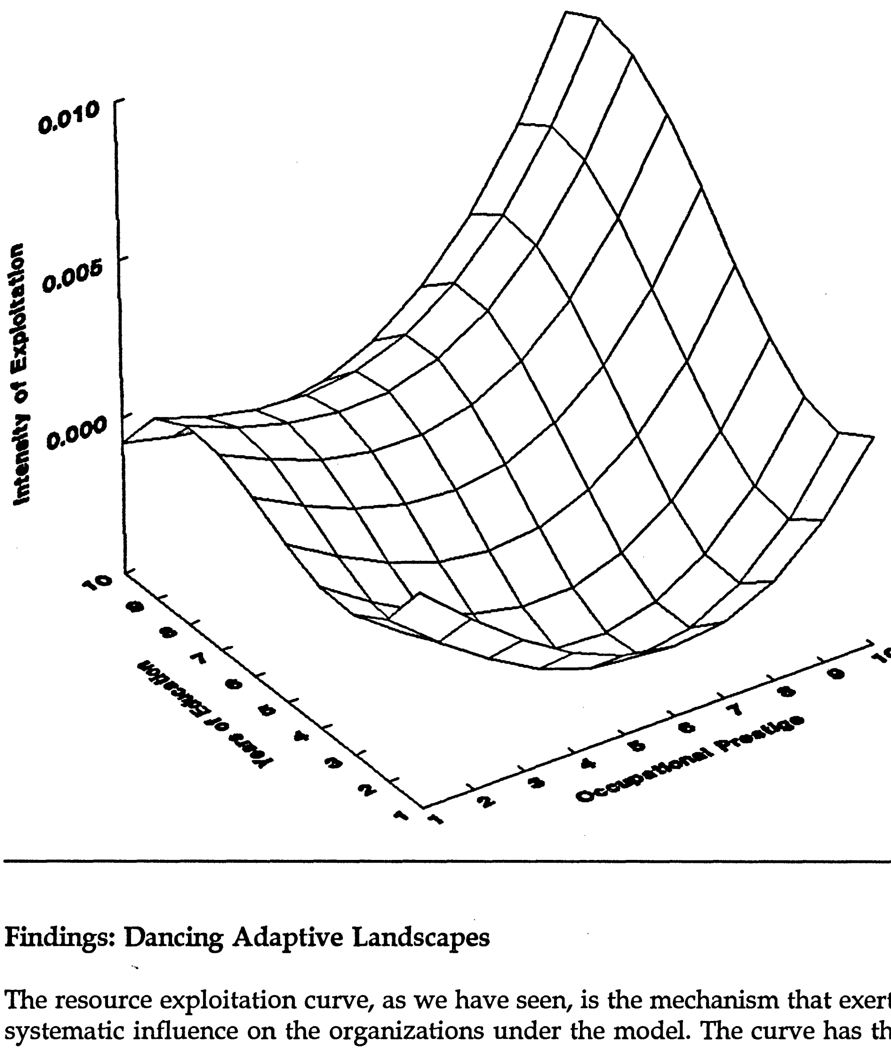
Information on the education and occupational prestige of the members of each type of organization provides an estimate of the niche location of the organizational type for that year. Evidence for the persistence of the niches appears in Figure 3, which gives the time path of the niches for six organiza-

FIGURE 3: Mean Education Level of Six Selected Voluntary Association Types



tional types over the fourteen year period of the data. The figure shows that the niches tend to track along in the same relative location over time in the educational axis of Blau space. The niches for the occupational axis behave similarly. If there were no niches at this level of aggregation, we would expect that the means for each organizational type would not show the obvious stability of Figure 3; the niche paths would be undifferentiated in the dimensions and would wander randomly. Of course, there is some variability in the organizational niches. The key question to ask of the data is whether these movements over time are in response to the competitive dynamics given by the theory. If an initially high rate of organizational overlap in a region is followed by a movement of the organizations away from that overlap, then the model is supported. On the other hand, if the movements are random, or counter to the predictions of the model, then we reject the theory.

FIGURE 4: Carrying Capacity for Organizations — GSS Voluntary Association Module (1974-1987)



Findings: Dancing Adaptive Landscapes

The resource exploitation curve, as we have seen, is the mechanism that exerts systematic influence on the organizations under the model. The curve has the dimensionality of Blau space; that is, it is a *K*-dimensional surface with peaks and valleys defining opportunities and restraints in each dimension. This surface is not fixed; on the contrary, it responds to shifts in the niches of all the organizations simultaneously. It will continuously dance with the rhythm set by the inputs of demographic changes and the responses of the organizations as they capitalize on opportunities and move away from costs. The frequency of these changes will depend on the frequency of the inputs and outputs.

The first task is to construct a representation of the carrying capacity for organizational membership. We focus on two of the Blau dimensions that are salient for group composition, occupational prestige and education (McPherson

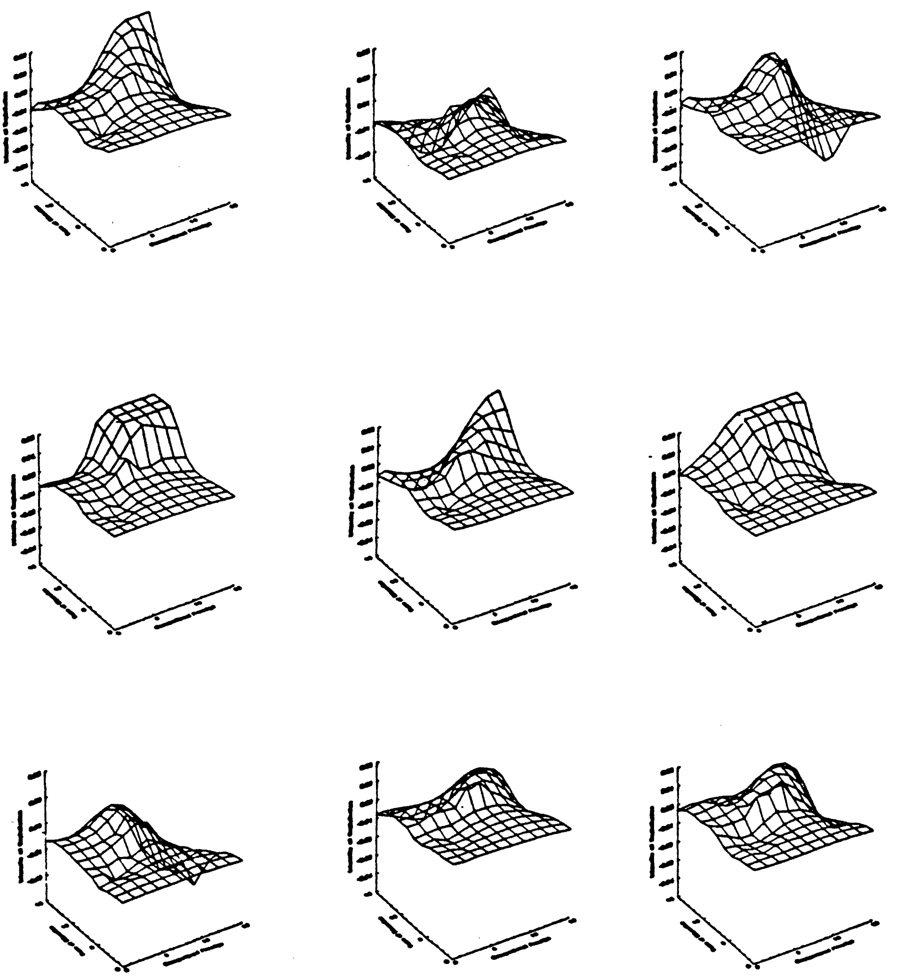
& Smith-Lovin 1987).[11] Figure 4 presents the estimated carrying capacity for the GSS data, for the two dimensions. This figure is a generalization of the carrying capacity in Figure 1 to two dimensions, estimated with GSS data. The height of the surface indicates the capacity for the system to sustain organizational memberships, taken as an average over the 14 year period. Confirming a finding common in the literature on voluntary associations, there is a general upward trend in the carrying capacity with increases in occupational prestige and years of education. This surface presents a great deal more information than the typical multiple-regression equation (e.g., Orum 1966) or cross-tabulation (Bell & Force 1956).

The carrying capacity is a feature of the distribution of individuals and memberships in Blau space. Since we cannot track the same people over time, we track regions of Blau space instead, under the assumption that since the GSS is a representative sample of individuals, each region of Blau space will be representative as well. Each dimension is divided into 10 equal intervals in its observed range, generating 100 subregions in the two dimensional space. We settled on 100 subregions as a reasonable compromise between statistical power in each cell and sufficient resolution in Blau space. The data from the entire 14 year period are pooled, and the average rate of affiliation for each subregion is calculated. These rates are then smoothed with a polynomial regression analysis to produce a continuous surface across the space.[12] The surface is smoothed to reflect the idea that the carrying capacity is a result of the underlying social networks through which the organizations recruit.[13] These networks are continuously connected through Blau space with no discontinuities across the Blau dimensions we have chosen (cf. Marsden 1987).

The next task is to estimate the short-term deviations from the carrying capacity, which the model argues should produce systematic group changes. These deviations produce the dancing adaptive landscape on which the groups compete for members. For each year of the GSS data, the deviations from the carrying capacity surface are calculated for each region of the space. This produces a vector of 100 residuals from the surface for the nine waves of the study.[14] A representation of these residuals for each of the nine waves of observation is presented in Figure 5. The dancing landscapes are the residuals from the carrying capacity of Figure 4, for each time period. As the figure shows, there is a great deal of movement in the surface from period to period, with peaks and valleys appearing and disappearing. These peaks and valleys capture the forces operating upon the groups in each time period under the model. Our hypothesis is that the group should move toward the valleys and away from the peaks.

To test this hypothesis, we estimate the position of the center of the niche for each organization type for each year (as in Figure 3). The opportunities for organizations are then evaluated within a window (1.5 standard deviations) around the niche position for each organizational type.[15] The opportunities on the adaptive landscape in each direction within that window are evaluated in the following way. The exploitation surface for any given year is the arithmetic difference between the carrying capacity and the observed rate of organizational membership for that region of Blau space for that year. Recall that the carrying capacity is a smoothed average of the membership rate across the 14 year span

FIGURE 5: The Dance of the Adaptive Landscapes — GSS Voluntary Association Module (1974-1987)



covered by the GSS (cf. Figure 1 and note 13). The exploitation surface varies over both time and Blau space, as in equation 1,

$$\text{Exploitation}_{t,i} = \text{Membership}_{t,i} - \text{Capacity}_i \qquad (1)$$

where t varies over the 9 time periods, and i varies over the 100 cells defined in Blau space. For each organization, the value of the exploitation function in each direction within the window is cumulated and the result is compared with the cumulant for the opposing direction. If the cumulant is negative to the right (for instance, if the exploitation curve drops systematically to the left of a group in the education dimension) and positive to the left, then the signed differences in the cumulant predict a negative movement (to the left). If the cumulants balance, then no movement is predicted. If the cumulants are imbalanced to the other direction, opposite motion is predicted:

$$\text{Net opportunity}_{t,j,k} = \text{Right cumulant}_{t,j,k} - \text{Left cumulant}_{t,j,k} \qquad (2)$$

where t varies over the 9 time periods, j varies over the 16 organizational types, and k varies over the dimensions. These calculated opportunities are the independent variables in two sets of regressions that predict the displacement of the niche in each dimension:

$$\text{Niche movement}_{t,j,\text{OCC}} = .020 + 37.359 * \text{Net opportunity}_{t,j,\text{OCC}} \qquad (3)$$

$$\text{Niche movement}_{t,j,\text{EDUC}} = .084 + 20.800 * \text{Net opportunity}_{t,j,\text{EDUC}} \qquad (4)$$

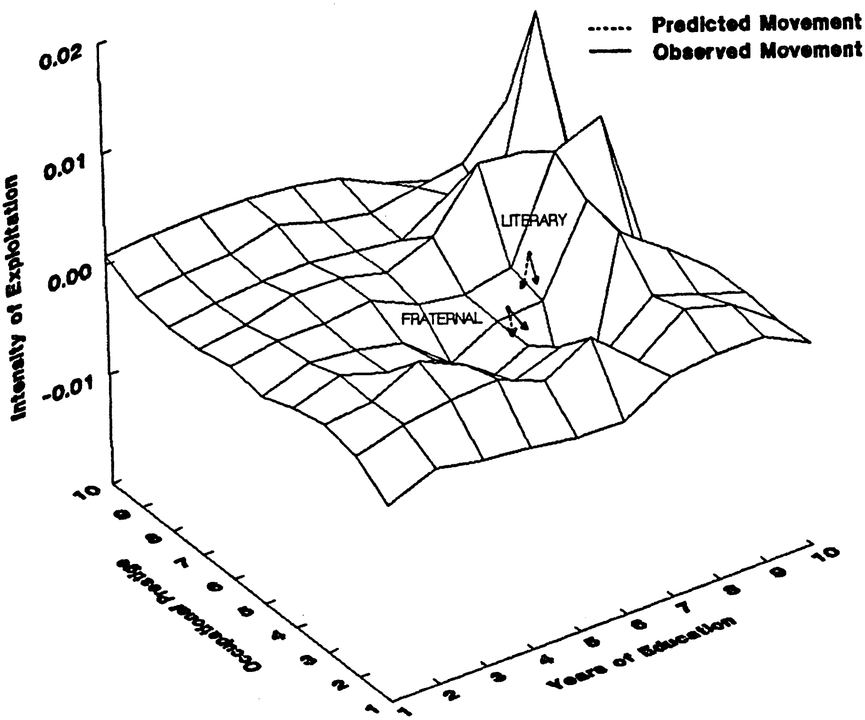
where t now varies across 8 time periods (since the movement is obtained by subtraction of position at t and t-1), and j varies across the organizational types. Niche movement is the observed mean difference in location of the organizational niche between two adjacent waves (the motion plotted for all time periods in Figure 3). Both of the coefficients for opportunity in equations 3 and 4 are significant beyond the .05 level,[16] although the amount of explained variance is modest (R=.16 and .28 respectively).[17]

Equations 3 and 4 predict movement in both dimensions simultaneously, in the sense that the predictions consider the curvature of the exploitation surface in both dimensions at once. Although the equations decompose the vector of movement into two orthogonal dimensions, the opportunity variable considers the local shape of the exploitation surface for the observed value of the dimension not varying in the equation. For each organization, the net opportunity is calculated in each dimension at the value of the other dimension actually occupied by the organization. Thus, a unique predicted position is produced by the model that considers the multidimensional curvature of the opportunity space.

Two selected organizations and their behavior under the model are shown on Figures 6 and 7, which are more detailed versions of two of the landscapes in Figure 5, rotated to give a slightly better perspective. The predictions for selected organizational types are presented as dotted lines, while the actual movements are solid lines. The figure illustrates the correspondence between the predicted and observed movements for these groups. As the figures show, there is a distinct correspondence between the predicted and observed movements, but the correspondence is not perfect. That we can detect any systematic movement at all is a tribute to the power of the model, given the extremely high level of aggregation.

One consequence of the high level of aggregation is that the niches as measured mix true between and within organizational variance and attribute it to within variance. Since we have to aggregate over many organizations to get an estimate of the niche of the type at the national level, we overestimate the niche width. Unfortunately, we cannot simply adjust our niche width, since the movements of the niches depend mostly on the memberships at the edges of the

FIGURE 6: Two-Dimensional Adaptive Landscape with Observed and Predicted Organizational Movement (1975)

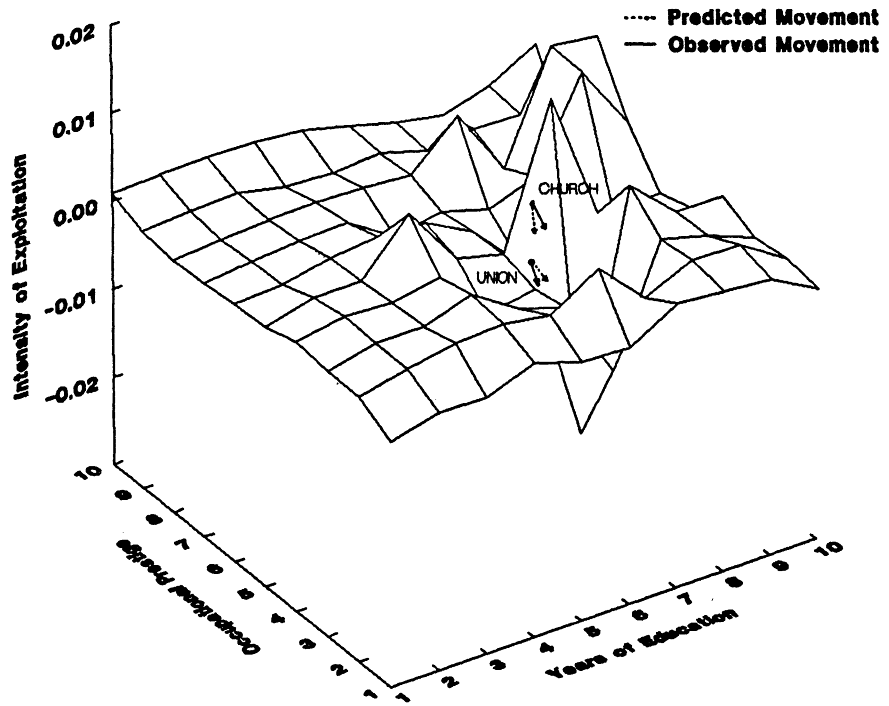


niche. The net result of the aggregation is that all the organizational types at this level of aggregation encompass very large areas of Blau space in their niches. The fraternal groups in Figure 6 illustrate one consequence of this large niche width; the predicted direction is not toward the deep indentation nearby in the surface but off toward the shallow trench in the negative direction of the education dimension. Since the organization is looking out so far in the education dimension, the cumulative effect of the systematic trench in the negative direction outweighs the local steep opportunity next door. Nonetheless, we still detect effects of the process at this level of aggregation. While the effects observed are modest, they are clearly supportive of the model. We await data on communities of actual organizations over time to test other aspects of the theory, such as the effects of the adaptive landscape on niche width, growth and decline, and other features.

Discussion

The great advantage of a Darwinian mechanism for organizational dynamics is that the Darwinian model of evolution is the only non-Marxist model capable in principle of accounting for the transformation of the entire system over time.

FIGURE 7: Two-Dimensional Adaptive Landscape with Observed and Predicted Organizational Movement (1983)



The Darwinian principle of selection and retention describes the time path of the entire set of life forms on earth through the interaction of populations of organisms. The Darwinian mechanism is irreversible in the sense that once a community of species has adjusted to a new set of environmental conditions, the old equilibrium cannot reappear. The new information contained in the structure of the current configuration of species precludes returning to the old state. Thus, the time path of each species as it negotiates its adaptation to each neighboring species is unique.[18] Our evolutionary model is similarly irreversible in the sense that the system will never return to a former state with the same members in the same organizations.

This irreversibility is an obvious property of society. We cannot remake the United States of the nineteenth century by banning the automobile. The existence of a social form shapes the future course of events irretrievably, just as the evolution of humans did through the mammalian branch, rather than the reptilian. The Darwinian mechanism has shown that it can account for these vast transformations of the entire system of life; our contention is that it can account for much of the transformations we observe in social life. The simple mechanism of member selection we posit for the evolution of social groups provides a starting point for interpreting some aspects of the long sweep of history, as well as making explicit the linkages between individual and organizational demography. We hope that our model of short-term adaptive changes in Blau space may eventually lead us to a way of integrating models of selective processes at other levels, such as the level of the organization (Bidwell & Kasarda 1985; Hannan & Freeman 1977) and the cultural trait (Cavalli-Sforza & Feldman 1981).

The theory contains an account for the impressive diversity of forms found in the voluntary sector. One of the basic problems faced by researchers of voluntary organizations (and organizations in general) is the bewildering array of different kinds of groups. Our model is a unified view of one process that underlies all this otherwise confusing diversity. By grounding the model in universal aspects of organizations (i.e., all organizations contain people), sociodemographic variables (i.e., all individuals have a value of age), and social networks (i.e., all networks are homophilous),[19] and ignoring the aspects for which we cannot yet account (i.e., organizational goals, individual utilities, the content of social networks), we avoid the pitfall of focusing on uniqueness at the expense of generality and redirect attention to those phenomena that we may be able to explain.

At the same time, the model articulates well with existing theories of organization. There is a substantial connection between this model and the developing view that organizational formation is embedded in social networks (Granovetter 1978, 1985). The model provides an interesting and potentially fertile contrast with the collective-action approach to group dynamics in Oliver, Marwell and Teixeira (1985), Oliver and Marwell (1988), and other articles in that tradition. In a sense, our theory is the sociological dual of their collective action approach; that theory is about the aggregation of individual choices while this theory is about the limits of choice.

The evolutionary model may provide a common ground for institutional theory (Meyer & Rowan 1977) and the ecology of organizations (Aldrich 1979; Hannan & Freeman 1977). For instance, we would like to know what happens to the rules in groups when the social composition of the group changes in response to adaptive process in Blau space.[20] If the rules change, one might be able to make arguments for the primacy of one theory over another in a common domain. The comparison between the two theories in this article is simply an answer to the question of whether we can detect any effects of the evolutionary process. The fact that we find small but detectible effects of the adaptive landscape implies at least that the institutional view is not the only argument worth making about dynamics at the level of the organization. A more interesting contrast between the two views will be possible when data on actual organizations in community systems over time are available.

The evolutionary theory may have useful applications outside the organizational realm. It essentially hinges on two axioms. The first is that the events we observe (group dynamic behavior) depend on propagation through social networks. The second is that the networks are homophilous. The theory should apply to any social phenomena in which these conditions are fulfilled. Possibilities include the spread of social movements (McAdam 1986), labor markets (Kalleberg & Sørensen 1979), family (Giele 1979), collective behavior (McPhail & Wohlstein 1982), and community (Laumann, Galaskiewicz & Marsden 1978).

The essence of the model is the idea that groups recruit new members like the old ones. The power of the model comes from specifying exactly what kind of similarity is important and how the process of recruitment is shaped by the social network. The model has the potential to tie together research on social networks and organizations to produce a theory of community ecology and community evolution. The long-term payoff for the approach we take lies in the connections the model makes between classical sociological theory, evolutionary theory, and contemporary theories of social networks and social organization.

Notes

1. This version of the sociological view of history is not offered as a model correct in detail but as representative of the sociological perspective on the long run of history. For a stimulating contrary view, see Tilly 1984.

2. There is an implicit order in the Blau dimensions produced by their developmental sequence. The most biologically relevant dimensions like age and sex are the first to become relevant in the distinctions among individuals in society. As the process of differentiation in social networks unfolds, more abstract dimensions such as occupational prestige come into play. In large, highly differentiated systems, extremely abstract and socially constructed quantities such as beauty can become quite powerful (Webster & Driskell 1983).

3. The relationship between the dimensions and the organizational and institutional structures that operate in them is coevolutionary. That is, homophily is at once a cause and a result of the operation of social structure. Individuals meet in organizations composed primarily of similar people (Feld 1981, McPherson & Smith-Lovin 1987); these connections between similar individuals then increase the probability that future group formation will be homophilous. Carley (1986) suggests that one force driving homophilous group formation is the fact that similar individuals will tend to have a greater percentage of information in common. This fact facilitates communication between similar individuals and hinders coordination with dissimilar ones.

4. To illustrate the simplification involved, suppose we want to describe the relationship between two arbitrary individuals in each type of system. In the first case, we have to trace all the connections between the two individuals over the K different types of network contacts. We would summarize the result with a statement such as: "person A is connected to person B through three intermediaries in the economic exchange network, by two intermediaries in the marital network, by one intermediary in the cousinship network, . . ." Note that we are using here only the simplest information about these netsworks, the minimal spanning arc (Harary, Norma & Cartwright 1966). A complete description would require descriptions of all paths linking A and B in the networks — a number that is likely to be astronomically large for systems of any size. On the other hand, in the second case our statement would be more like: "person A is two units from person B in the education dimension, 1.5 units in the occupational prestige dimension." The relative positions of A and B can be described completely with K pairs of numbers.

5. Granovetter (1973) argues that when connections at great distances do occur, they are likely to involve novel information to the two parties, since information tends to be localized in the net.

6. This is one of the points at which our analysis differs substantially from the collective action perspective of Oliver and associates (1985); we believe that group formation is determined by general constraints in the social network rather than by individual utilities, or imputed production functions. We are interested in the contrast between groups formed with groups that could never have formed (because the members are not connected with one another). What drives the system is not that individuals are making choices to participate in some collective action or not but that most of the logically possible choices are eliminated by structure in the social network.

7. All forms of organizations recruit through social networks, including firms (Granovetter 1974, Marsden & Campbell n.d.) cults and sects (Stark & Bainbridge 1980) and social movements (Snow, Zurcher & Ekland-Olson 1980).

8. The carrying capacity is responsive to macroevolutionary (Simpson 1944) trends, as discussed earlier. Changes in the size and structural differentiation of society, the resulting changes in the demographic structure, technological advances in transportation and communication, and other long term trends condition the shape of the carrying capacity for organizational activity. We speculate that these variables can account for the great differences observed in rates of voluntary affiliation in different nations (cf. McPherson 1981; McPherson & Smith-Lovin 1988).

9. We emphasize the static side of institutional analysis to create a conceptual contrast in the context of our data. We recognize the potential of the institutional approach to account for the spread of social forms, to structure change, and so forth.

10. The types are: fraternal, service, veterans, political, unions, sports, youth, school, hobby, school fraternal or sororal, nationality, farm, literary, professional, church related, and other.

11. We ruled out categorical Blau dimensions for technical reasons having to do with the difficulty of operationalizing carrying capacities for them. Another prime candidate, age (cf. Knoke & Thomsen 1977), presents special difficulties because all individuals in the system are changing on this variable continuously, while some organizations (e.g. social groups) are tracking along with cohorts and others stay fixed at given ages (e.g. youth-related groups). The age dimension will be the subject of a separate paper. We do not argue that we have measured all, or even most, of the important Blau dimensions that affect organizational dynamics.

12. The fitted polynomial was:

$$Y = 6.4 * 10^{-3} -1.6 * 10^{-3}(ED) -3.8 * 10^{-3}(OC) +4.1 * 10^{-6}(ED^2) + 7.9 * 10^{-4}(OC^2) + 1.3 * 10^{-5}(ED^3) - 4.8 * 10^{-5}(OC^3) + 1.1 * 10^{-4}(ED * OC),$$

where *ED* is years of education and *OC* is occupational prestige (multiple R=.741). See Box and Draper (1987) for a general discussion of fitting response surfaces.

13. The choice of number of intervals and the choice of smoothing functions are not trivial, since the ruggedness of the adaptive landscape affects the ability of groups to move through the system. Our decisions about parameterization were based on a search through a range of possibilities (e.g., from 5 to 20 intervals, polynomials of higher order, windows of different widths) within the limits of the data and the capacity of the IBM 3090-600E supercomputer.

14. A pooled cross-section time-series analysis of the 16 types of organizational memberships over the 9 time periods suggests that the times series is stationary. That is, the period-specific deviations from the surface presented in Figure 5 appear to return consistently to that surface; there is no discernible trend in the surface. We interpret this fact as evidence that we can regard the surface as the equilibrium value to which the system returns after perturbation (cf. Nelson 1973).

15. The opportunities are calculated by averaging the deviations from the carrying capacity in the vicinity of each organization. Concretely, the mean height of the adaptive landscape in each of the four possible directions, for a distance defined by the niche width window of 1.5 standard deviations (cf. McPherson 1983), is calculated by direct computation from the data. The differences in height in each direction then produce the prediction for movement of the organization. We experimented with a range of window sizes from .5 to 2.5 standard deviations, to test the sensitivity of the model to the window parameterization. The window width used by McPherson (1983) and McPherson and Smith-Lovin (1988) was 1.5 standard deviations; this appears to be the optimal window width for the present study as well. The effects under the model disappear when the window is too small (.5 standard deviations) and too large (two or more standard deviations). This result is consistent with our contention that the important recruitment and loss dynamics occur at the fringe of the niche, rather than at the center or outside the niche. Note that this window of 1.5 standard deviations is also very near the optimal value for some bioecological applications (e.g., Levins 1968).

16. Statistical significance is heuristic, since no inferential theory exists for this application. We performed a bootstrap analysis of the estimated model of equations 3 and 4, and in no case did the pseudoreplication confidence intervals include 0. This result gives us reason to believe that the estimates in equations 3 and 4 represent reproducible findings. The possibility that the

model capitalizes upon sampling fluctuations in the memberships for each type across the waves of observation still cannot be completely ruled out since we cannot distinguish changes in organizational means due to sampling fluctuations from "true" changes. The bootstrap analysis is one avenue for dealing with this possibility; the issue is being investigated further with machine-intensive methods. There are 26,258 memberships in the 16 organizational types among the 23,356 individuals in the 9 time periods. The degrees of freedom in the reported results are 16 types by 9 time periods equals 144, less one wave of observations, giving initial conditions 128.

17. Some detail on the scales of these variables is in order. The cumulants of equation 2 are in a scale defined by the difference in two surfaces, the carrying capacity and the exploitation surface for a given year. The theoretical maximum for this difference is less than +1 unit, representing the case in which deflection of the exploitation surface was maximally concentrated in one cell of Blau space. Likewise, the theoretical minimum is greater than -1 unit. An organization that perfectly spanned two maximally deflected cells in the space could conceivably have an opportunity coefficient in the range -2 to +2. Thus, a one unit value of opportunity is quite unlikely; in fact, the maximum observed value is slightly less than .01 (0.00927). The maximum observed change in the niche location is .653 units. Recall that the niches are defined in 10 equal intervals across the observed range of occupational prestige and education. Thus, a coefficient of 37 means roughly that the maximum amount of observed opportunity would produce a predicted movement of about one third unit in the niche dimension.

18. The literature on bioevolution has many discussions of convergent evolution (Dawkins 1986; Futuyma 1986) in which a structure has arisen independently in solution to similar environmental constraints. These traits are not a result of direct descent but rather appear when environmental contingencies are similar.

19. The marriage relation is an obvious exception.

20. Early work on process can be found in Zald (1970), and Zald and Denton (1963).

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