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SOCIAL NETWORK ANALYSIS AND INTERCORPORATE RELATIONS*

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The concept of 'social network' has been a powerful idea in social research. It implies an image of individuals tied to one another by invisible bonds knitted together in a criss-cross mesh of connections, much as a fishing net or a length of cloth is made from intertwined fabrics. Social network analysis has developed as an approach which attempts to take this metaphor seriously and to develop its theoretical basis, and in recent years it has spawned a number of sophisticated technical methods for charting the mathematical features of social networks. In this paper I will outline the key ideas of social network analysis, and I will illustrate the application of these ideas to the study of intercorporate relations in business.

Origins of Social Network Analysis

Although the early sociologists used the terminology of 'social bonds' and 'webs of connection' to express the idea of 'society' as a structural reality with distinct properties of its own, capable of exercising constraint over the actions of individuals, they used the notion of social network only as a metaphor. The first true formulations of social network analysis, in which the metaphor was taken seriously as the basis for developing a battery of sociological concepts, took place in the American social psychology of the 1930s. Moreno developed what he called 'sociometry' as a way of conceptualising the structures of the small groups which were produced through friendship choices and informal interaction. Moreno drew 'sociograms' in which lines between points represented the friendship choices made by the people represented by the points. Those who were especially popular in the social group received many friendship choices and appeared as 'stars' or 'hubs' in the sociograms: they appeared as points from which numerous lines radiated. This approach was systematically developed by writers on 'group dynamics,' the backbone of American social psychology in the 1950s and 1960s.[1]

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[1] For the development of this approach see J.L. Moreno, *Who Shall Survive?*, New York, Beacon House, 1953 (original version published in 1934); A. Bavelas, 'A Mathematical Model for Group Structure,' *Applied Anthropology*, 7, 1948; L. Festinger, 'The Analysis of Sociograms Using Matrix Algebra,' *Human Relations*, 2, 1949; D. Cartwright and A. Zander, eds, *Group Dynamics*, London, Tavistock, 1954.

Independently of these developments, certain British sociologists and anthropologists also began to develop social network analysis. John Barnes, studying the activities of fishermen in Norway, came to realise the close analogy between the nets used by the fishermen and the social structure of the village in which they lived. This insight was fruitfully developed in subsequent research, initially by those studying African tribal societies and urban communities and by those studying family and community structure in Britain. In these works, the concept of social network was used to describe variations in the quality of kinship relations and their connection with wider communal patterns of neighbouring and working.[2]

The central idea in both the American and the British work was a concern for the structural properties of networks of social relations. The aim of the researchers was to introduce novel concepts to describe these properties. In the work of social psychologists particular attention was given to the 'centrality' of different actors in the patterns of communication in small groups, while sociologists and anthropologists were more interested in what they variously described as the 'density' or 'connectedness' of social networks. Though evolving novel concepts, these writers did not advocate network analysis as a specialised technique within sociology. Social network analysis was not simply to supplement the existing battery of statistical and other mathematical methods. Rather, they sought to emphasise that there was something fundamentally wrong with a sociology which did not recognise and take seriously the patterns which were formed by social relations. Social network analysis, therefore, offered a new way of looking at old problems, a new perspective in which the metaphors used by sociologists since the founding of the discipline could be forged into powerful theoretical concepts.

Paradoxically, however, it was an upsurge of interest in the mathematics of network analysis which was responsible for a major expansion in social network analysis in the 1960s and 1970s. In geography, economics, and linguistics, as well as in sociology and anthropology, more and more social scientists became convinced of the power inherent in social network analysis and sought to extend the scope of its application. Especially important were the large number of new recruits to the expanding American graduate schools, whose expertise in what threatened to become a rather esoteric technique was of considerable value in promoting their professional careers and in establishing social network analysis. A key role in the development of social network analysis, and in helping to translate the mathematical formulations into meaningful research programmes, was played by the group of graduates trained in Harvard's Department of Sociology by Harrison White. This group of sociologists, including Stephen Berkowitz, Joel Levine, Michael Schwartz, and Barry Wellman, furthered social network analysis as they moved from Harvard to their first professional appointments in universities throughout North America. By the middle of the 1970s, social network analysis had become established as a research specialism with an inter-

[2] The original paper is J.A. Barnes, 'Class and Committees in a Norwegian Island Parish,' *Human Relations*, 7, 1954. For anthropological studies see M. Fortes, *The Web of Kinship Among the Tallensi*, Oxford University Press, 1949; S.F. Nadel, *Toward a Theory of Social Structure*, London, Cohen and West, 1962, and J.C. Mitchell, ed., *Social Networks in Urban Situations*, Manchester University Press, 1969. Family and community studies include E. Bott, *Family and Social Network*, London, Tavistock, 1957; M. Young and P. Willmott, *Family and Kinship in East London*, London, Routledge and Kegan Paul, 1957; and R.J. Frankenberg, *Communities in Britain*, Harmondsworth, Penguin, 1966. These two traditions are brought together in M. Banton, ed., *The Social Anthropology of Complex Societies*, London, Tavistock, 1966.

national base.[3]

This group of researchers—a network of networkers—was not, however, an enclosed specialism sharply separated from others, though it had established its own journal (*Social Networks*) and newsletter (*Connections*)[4] Social network analysts were drawn from a diverse range of specialisms, ranging from the traditional concerns of family and community structure and group dynamics to such areas as elites and power, interlocking directorships, labour market studies, social stratification, science citation studies, health and welfare provision, crime and deviance, and the global economy. Network analysts were, in fact, to be found in almost all areas of sociological specialisation. What united them was a commitment to the underlying frame of reference of social network analysis, which illuminated the common structural concerns of researchers in these diverse areas. The leading writers in North American social network analysis have forcefully reiterated the claim that the network concept is central to sociology, and is the most fruitful way of developing that structural analysis which the classical sociologists emphasised as the distinguishing feature of the discipline as a whole.[5]

Models for Social Networks

The central question in the development of social network analysis has been that of how the metaphor of a social network is to be taken seriously. Social network analysis depicts agents—individual or collective—as embedded in webs of connections, and the task of the sociologist is to describe and explain the patterns exhibited in these connections. The image of a fishing net, with its knots and tangles and its variations of fine and open mesh, is close to our everyday imagery of social relations, but how is this to be converted into a useful sociological concept?

At its simplest, the idea of a network involves a set of points connected by lines, and it was this idea which led the earliest proponents of social network analysis to turn to the mathematical theory of graphs in the hope of discovering a formal model for the representation of network structure. The formal concepts of graph theory have been raided by sociologists, who have seen this as a straightforward way of evolving novel sociological concepts. Social scientists cannot, however, simply turn to graph theory—or any other branch of mathematics—and mechanically apply it to the study of social relations. It is always necessary to decide which measures are theoretically and empirically appropriate for the subject under investigation. Mathematics can be an extremely powerful aid to social network

[3] A good account of this group of researchers can be found in N.C. Mullins, *Theory and Theory Groups in Contemporary American Sociology*, New York, Harper and Row, 1973.

[4] *Connections* is published three times each year, and is available to members of the *International Network of Social Network Analysis*. INSNA is organised by Barry Wellman, Centre for Urban and Community Studies, University of Toronto, 455 Spadina Avenue, Toronto, Canada, M5S 2G8.

[5] See B. Wellman, *Network Analysis: From Method and Metaphor to Theory and Substance*, Working Paper Series 1B, Structural Analysis Program, University of Toronto, 1981; S. Berkowitz, *An Introduction to Structural Analysis*, Toronto, Butterworth, 1982; S. Berkowitz and B., Wellman, eds, *Structural Sociology*, Cambridge University Press, 1988. For earlier reviews see J. Barnes, *Social Networks*, Module in Anthropology No., 26, Reading, Massachussetts, Addison Wesley, 1972; J.C. Mitchell, 'Social Networks,' *Annual Review of Anthropology*, 3, 1974.

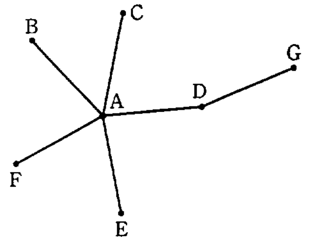
analysis, but it can never remove the need to make theoretical and empirical decisions about the significant sociological properties of social networks. It is for this reason that graph theory has not gone unchallenged, and alternative models for social networks have been proposed.

With this proviso in mind, it is possible to review the basic ideas of graph theory. The earliest codifications of graph theory aimed specifically at sociologists were those of Coleman, Harary *et al.*, and Doreian.[6] The mathematical concept of a graph involves the idea of *points* connected by *lines*, and graph theory comprises a set of procedures for analysing the presence, direction, and strength of the lines which connect the points. Figure 1 depicts a simple graph, and this will be used to illustrate some of the basic graph-theoretical ideas.

In Figure 1, seven points are labelled A to G. These points are connected by six lines. It is important to emphasise the fact that the arrangement of the points and lines on the page is purely arbitrary. The researcher can rearrange these as he or she sees fit, as it is only the pattern of *connections* that is important. Thus, points B and F appear closer on the page to one another than do points B and E, but this is purely an artifact of the way in which the diagram is drawn. Graph theory takes no account of conventional notions of physical distance, and sees the 'distance' between two points solely in terms of the number of lines which it is necessary to traverse in order to get from one point to another. The graph distance from B to F, therefore, is two lines (BA and AF), which is exactly the same as the distance from B to E (through lines BA and AE). The distance between any two points in a graph, then, is equal to the number of lines in the path between them: the distance from B to G, for example, is three lines.[7]

Two points connected by a line are said to be 'adjacent' to one another. The graph in Figure 1 consists of six adjacent pairs of points chained together (AB, AC, AD, AE, AF, and DG), but a central principle of network analysis is that the structure of a network must not simply be reduced to the properties of its individual parts. Thus, the network analyst must search for structural features of the graph as a whole. It is clear, for example, that point A occupies some kind of central position in the graph, and its centrality derives from

FIGURE 1



[6] J.S. Coleman, *Introduction to Mathematical Sociology*, New York, Free Press, 1964; F. Harary, R.Z. Norman, and D. Cartwright, *Structural Models*, New York, Wiley, 1965; P. Doreian, *Mathematics and the Study of Social Relations*, London, Weidenfeld and Nicolson, 1970.

[7] Strictly speaking, distance is measured only by the length of the shortest path between two points. If points C and D in Figure 1 were directly connected by a line, there would be two distinct paths connecting B and G—one of length three (BADG) and one of length four (BACDG). In more complex graphs there may be numerous alternative paths of varying length, and so distance is standardised to the shortest path.

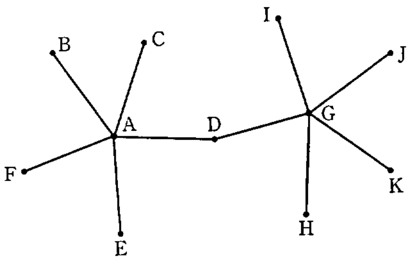
its involvement in five of the six pairs. Removing A from the graph would fundamentally alter its structure, while removing B would have far less impact. Graph theory formalises this notion of centrality through a measure of 'adjacency.' The adjacency of a point is simply the number of other points to which it is adjacent, and it is easy to calculate for Figure 1 that A has an adjacency of five. This compares with an adjacency of two for point D and an adjacency of one for each of the other points. Thus, by calculating the adjacencies of all points in a graph it is possible to discover which are most central to it.

It is perhaps important to emphasise again how graph theory departs in some respects from commonsense ideas. A central point in a graph is not like the centre of a circle: it is not to be thought of as somehow 'in the middle' of the graph. The adjacency of a point measures its centrality only among those points in its immediate vicinity, and a complex network may contain a large number of such central points. For this reason, graph theorists have developed a range of other measures of centrality, aimed precisely at distinguishing those points which are locally central from those which occupy a global position of centrality in the network as a whole.[8]

The graph theoretical idea of centrality was important for the psychologists concerned with the sociometric 'stars,' the centres of attraction in small groups. The early British social network analysts, on the other hand, were far more concerned with the 'density' of the networks which they studied. In graph theory, density is the ratio of the actual number of lines in the graph to the number which would be present if all points were connected to all others. It is logically possible for seven points to be completely connected through 21 lines—each pair of points connected by a line.[9] The seven points in Figure 1 are actually connected by only six lines, and so this graph has a density of 6/21, or 0.29, indicating that slightly under one third of the possible lines are present.

As the measure of density can vary from zero to one, the graph in Figure 1 would seem to have a moderately low density. But this may be a misleading line of reasoning to follow when dealing with the graph of a social network. The number of contracts which a person can sustain varies with the nature of the social relationship involved, and this imposes limits

FIGURE 2



[8] See, for example, L.C. Freeman, 'Centrality in Social Networks,' *Social Networks*, 1, 1978, and P. Bonacich, 'Power and Centrality: A Family of Measures,' *American Sociological Review*, 1987.

[9] The number of possible pairs is actually 42 (i.e., 7×6), but in an 'undirected graph' the line connecting A to B, for example, is regarded as identical to the line connecting B to A and so the number of distinct pairs is 21.

on the maximum density. While it is possible for the 500 people working in a factory to be 'aware' of one another as members of the organisation, it is unlikely that they would all be able to 'love' one another. The maximum density for the relation of 'awareness,' therefore, may be one, while the maximum density for the relation of 'loving' might be much lower. Similarly, it is difficult for one individual to hold more than a relatively small number of independent directorships, and so the maximum density of a network of interlocking directorships would also be low. An assessment of the actual density discovered in a social network, therefore, must take account of the *size* of the network (how many people are involved) and the *type* of relation (the ability of people to sustain contacts). The mathematical properties of the density measure must not blind the researcher to its substantive implications. A graph density of 0.29, for example, may, under certain circumstances, indicate a very high level of cohesion in the social network which it represents.[10]

Density measures have been used to identify the existence of 'clusters' in a graph, though this is not the only way in which clusters have been defined.[11] A cluster can be seen as a relatively densely-connected clump of points within a larger, and less dense, graph. Figure 2 shows an enlarged version of Figure 1. In this graph, point G is shown as being connected to four additional points (H, I, J, and K). The overall graph could be interpreted as comprising two clusters—(A, B, C, D, E, F) and (G, D, H, I, J, K)—and these two clusters would be connected through their common member, D. This graph contains ten lines and eleven points, giving it an overall density of 0.18. The two clusters stand out because they each have a density higher than that of the whole graph. However, the identification of clusters always depends upon the decision of a researcher as to what is to be treated as an acceptable level of density to define clusters in the particular network in question.

Closely allied to the concept of cluster is that of 'clique,' though this too has been defined in numerous ways. Where a cluster is most usefully seen as an area of a graph with relatively high density,[12] a clique is an area in which all points are connected to one another by paths of a specified maximum length. If the maximum distance acceptable to the researcher is set at one line, then a group of points would have to be 'completely connected' (each point directly connected to all others) in order to qualify as a clique. A less restrictive criterion would be to allow a maximum distance of two, in which case a clique would comprise a number of points which were either directly connected or connected through a common neighbour. On this criterion points A to F in Figure 1 would constitute a clique, as no point is further than two steps from any other. In that graph, therefore, only point G would lie outside the clique, as it is a distance of three lines from all points except A and D. Were the maximum path length for clique identification to be set at three lines, the whole graph in Figure 1 would comprise a single clique. The decision as to what is and what is not acceptable as a criterion for clique identification rests, once more, with the researcher.

This rapid review has ignored some of the diversity in terminology and conceptualisation which exists, since its aim has been to bring out the important ideas shared by graph theorists.

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[10] See J. Barnes, 'Network Analysis: Orienting Notion, Rigorous Technique or Substantive Field of Study?,' in P.W. Holland and S. Lienhardt, eds., *Perspectives on Social Networks*, New York, Academic Press, 1979, and N.E. Friedkin, 'The Development of Structure in Random Networks,' *Social Networks*, 3, 1981.

[11] A review of methods can be found in B. Everitt, *Cluster Analysis*, London, Heinemann, 1974.

[12] This is a so-called sub-graph.

The important conclusion is that graph theory provides a powerful way of representing some of the principal features of social networks, but that it must not be applied in a mechanical way. The social scientist must always remain in command of the mathematics, rather than the mathematics determining its own applications.

Intercorporate Relations as Social Networks

How, then, can intercorporate relations in business be usefully translated into the formal concepts of graph theory? The overall network of intercorporate relations is a combination of a number of distinct networks: the network of personal relations, the network of capital relations, and the network of commercial relations.

Personal relations are those links between enterprises which result from the sharing or linking of personnel, and the most important of these are interlocking directorships and interconnections through kinship. If enterprises are considered as 'points' in a graph, then the sharing of a director by two enterprises can be understood as creating a 'line' between the points which represent them. Similarly, lines can result from the presence of members of the same family on different boards. Kinship networks have hardly been studied in a systematic way, despite their close association with other informal relations and the mechanisms of political power.[13] Perhaps the most sophisticated approach to this question is that of Zeitlin and Ratcliff,[14] which uses the graph theoretical concept of distance to represent genealogical distance in kinship networks and suggests that, for example, dynasties can be regarded as cliques in the network of lines of male descent. This raises the possibility of studying what I have called 'kinterlocks'—intercorporate links created by the presence of kinsmen on the boards of two distinct enterprises—but such relations are extremely difficult to trace and analyse. Because interlocking directorships, by contrast, are relatively easy to study, however, they have dominated the field of research on personal relations in business, and many writers have claimed that they can serve as proxies for capital and commercial relations.

An interlock is a social relation created by a *multiple director*, and the totality of multiple directors create a network of interlocking directorships whose structure can be studied using the techniques of graph theory. The number of interlocks generated by each multiple director is given by the formula $b(b-1)/2$, where b is the number of directorships held. Thus, a director with two directorships generates one interlock, a director with three directorships generates three interlocks, a director with four directorships generates six interlocks, and so on. The total number of interlocks in a network, therefore, is the sum of this total for all multiple directors. The total number of *lines* in a network is not, however, the same as the total number of interlocks. If company A and company B have two directors in common, there are two interlocks between them but only one line. In graph theory this is expressed by saying that the line AB has a 'multiplicity,' or 'value,' of two.

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[13] But see Whitley, cited in note 17; R. Whitley, 'The City and Industry,' in P. Stanworth and A. Giddens, eds., *Elites and Power in British Society*, Cambridge University Press, 1974.

[14] M. Zeitlin and R.E. Ratcliff, 'Research Methods for the Analysis of the Internal Structure of Dominant Classes,' *Latin American Research Review*, 10, 1975.

This relationship can be looked at in another way. An enterprise which is connected to two other enterprises has an 'adjacency' of two: it is involved in two lines. The sum of the adjacencies for all enterprises in a network is equal to twice the number of lines (as each line is counted twice), and it is, therefore, possible to arrive at a formula for the density. This is the ratio of the actual number of lines to the maximum possible number of lines, and can be summarised as $L/\{(n-1)/2\}$, where L is the number of lines and n is the number of points. This, measure of density takes no account of the multiplicity of the lines which make up the network, and it is necessary for the researcher to examine this question separately. Two networks with the same density may differ in terms of the multiplicities of the lines which make them up. Other things being equal, a network in which many of the lines have a high multiplicity shows that the enterprises involved have particularly *intense* relations with one another.[15]

From this starting point we can see how the analysis of interlocks can be pushed further. The 'centrality' of an enterprise, for example, is the number of lines in which it is involved—the number of other enterprises to which it is connected. It is, again, important to take account of the multiplicities of these lines, as this may affect the way in which the measure of centrality is interpreted. Cliques and clusters in a network of interlocks indicate groups of enterprises which may be subject to a degree of coordination in their behaviour because they are tied together through the board memberships of a relatively small number of individuals.

Capital relations are links of shareholding and credit which are created when one enterprise participates in the share capital of another or acts as a lender to it. Outside Japan, information on bank lending is extremely difficult to obtain, and so little or no work has gone into the exploration of banking networks. Shareholding information is also rather difficult to discover, but some recent attempts have been made to investigate shareholding networks. This has involved a move away from the relatively simple 'undirected' networks discussed above, to 'directed' networks of relations. If enterprise A invests in enterprise B, then the line may be regarded as directed *from* point A *to* point B. Graph theory describes the line as going 'out' from A and 'in' to B. In a directed network the adjacency of a point can be divided into two distinct measures, termed the 'in-degree' and the 'out-degree.' The out-degree of an enterprise is the number of other enterprises in which it invests; its in-degree is the number of enterprises which participate in its capital. The most useful measure of centrality, regarding this as an indicator of power, is the out-degree. In a directed network, outgoing and incoming lines are regarded as distinct from one another: A to B is not the same as B to A. For this reason, the formula for the density differs from that in an undirected graph. In a directed graph, the density is simply $L/n(n-1)$.[16]

I have only been able to indicate some of the ways in which intercorporate relations can be translated into graph theoretical terms, but I hope that I have been able to give some

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[15] This distinction between interlock and line is absolutely crucial to all the measures, but it is often confused in the literature in intercorporate relations.

[16] I do not propose here to look at networks of commercial relations, which raise different theoretical problems. Information at company level is difficult to obtain, and investigators in this area are hardly touched by developments in network analysis. The analysis of inter-industry input-output tables, however, can easily be seen in network terms.

idea of its power and sophistication. In order to take this further, I shall illustrate some of the uses to which these techniques have been put.

The Uses of Network Analysis

Interorganisational research on interlocking directorships was stimulated by Marxist discussions of the concentration of economic power, centred on the concept of 'finance capital,' and by those American liberals concerned with the threat to individualism posed by the 'Money Trust' of big bankers.[17] Although commentators and researchers from the early years of the century onwards spoke of the 'webs' and 'chains' of interlocking directorships which 'entwined' the major business enterprises, the concept of social network did not become a systematic research tool in this area until the early 1970s, when researchers in the United States and, soon after, in Canada, The Netherlands, Britain and elsewhere began to apply the techniques of network analysis. The first published outcome of this growth of interest was Levine's depiction of the structure of bank-industry interlocks in the United States. Interestingly, Levine did not use graph theory. Instead his approach drew on multidimensional scaling, an approach to which I shall return later.[18]

The most influential of these early studies was that undertaken by the Stony Brook group of researchers in an extremely influential unpublished paper.[19] These researchers studied interlocking directorships in large American enterprises during the period 1962–73, their interest being in the structure of the network as a whole. They found the existence of an extensive and relatively cohesive national network, but discovered a different pattern when they isolated the interlocks carried by those who were executives in the enterprises. These interlocks—termed 'primary interlocks'—were intense links which created close-knit, bank-centred groups with a distinct regional character.

These 'interest groups' were identifiable as cliques within the network of primary interlocks, and had some similiarities with the financial interest groups depicted in Marxist theory: they were structured around banks, and the interlocking directorships were associated with indebtedness, intercorporate shareholdings, and economic interdependence. The Marxist interpretation was rejected, however, because the cliques did not exist as sharply distinguished groups. The regional structure of 'strong ties' was embedded in a more extensive and loose-

[17] D. Di Donato, D.S. Glasberg, B. Mintz, and M. Schwartz, 'Theories of Corporate Interlocks: A Social History,' in S. Bachrach, ed., *Perspectives in Organisational Sociology*. See also J. Scott, *Corporations, Classes, and Capitalism*, Second edition, London, Hutchinson, 1985, Chapter 4.

[18] J.H. Levine, 'Spheres of Influence,' *American Sociological Review*, 37, 1972. The other American pioneers were J. Bearden, W. Atwood, P. Freitag, C. Hendricks, B. Mintz, and M. Schwartz, 'The Nature and Extent of Bank Centrality,' Paper to the American Sociological Association, 1975, and J.A. Sonquist, et al., 'Interlocking Directorships in the Top U.S. Corporations,' *Insurgent Sociologist*, 5, 1975. In other countries there were: R. Whitley, 'Commonalities and Connections Among Directors of Large Financial Institutions,' *Sociological Review*, 21, 1973; H.M. Helmers, R.J. Mokken, R.C. Plijter, and F.N. Stokman, *Graven Naar Macht*, Amsterdam, Van Gennep, 1975; J. Scott and M.D. Hughes, 'Finance Capital and the Scottish Upper Class,' in G. Brown, ed., *The Red Paper on Scotland*, Edinburgh University Student Publications Board, 1975; J. Scott and M.D. Hughes, 'Ownership and Control in a Satellite Economy,' *Sociology*, 10, 1976; P. Stanworth and A. Giddens 'The Modern Corporate Economy,' *Sociological Review*, 23, 1975.

[19] Bearden et al., *op. cit.*

knit national network in which the executive and non-executive directors of the New York banks played a key role. The interpretation placed on this structure by the Stony Brook researchers owed much to Granovetter's influential analysis of the important role played by relatively 'weak' ties in loose-knit networks.[20]

The most important concept to emerge from this work is that of 'bank centrality,' and this has been the foundation of much recent work aimed at building on the Stony Brook research. Particularly important has been the work of Mintz and Schwartz, who have claimed that 'bank centrality' in networks of interlocking directorships is indicative of the 'financial hegemony' of large financial institutions in the American economy.[21]

My own work has been heavily influenced by that of the Stony Brook group of researchers. Beginning with an investigation of interlocking directorships in Scotland and Britain, forming part of an international investigation of this issue, I have most recently begun to explore shareholding networks in Britain, the United States, and Japan.[22] Perhaps I can illustrate the use of social network analysis in my discussion of the intercorporate network in Britain.

The sector of big business in Britain has been studied over the period 1904–1976. It was found that the overall density of the interlock network increased from 0.013 to 0.017. This reflected an increase of over one third in the number of lines among the 250 enterprises studied. As the average multiplicity of the lines declined over the period—there were very few with a multiplicity greater than two in 1976—the number of interlocks did not increase by as much. There was a greater differentiation of the roles of multiple director and single director. The multiple directors were a smaller proportion of the total directorate in 1976 and they held, on average, a larger number of directorships than their counterparts of 1904. Over the same period there was a decline in the regional structuring of the network. Only Scotland maintained any kind of regional distinctiveness, due largely to the survival of a strong Scottish financial sector.

The importance of financial institutions in interlock networks is clearly brought out in my findings on centrality and cliques. In 1976 the ten most central enterprises included seven banks and one insurance company, giving strong support to the Stony Brook group's emphasis on bank centrality. As in the United States, banks were important in the network of primary interlocks. It was through the executive directors of financial institutions that financial and non-financial enterprises were tied into a single network centred on the major banks. When cliques in this network were explored, it was discovered that there were eight cliques, six of which had banks at their centres. These were interpreted as bank-centred spheres of influence, rather than financial interest groups, as the cliques were loose, overlapping, and embedded in a more diffuse network. Banks were seen as exercising a generalised hegemony in the intercorporate network, maintaining only loose alliances with their leading customers, clients, and associates.

[20] M. Granovetter, 'The Strength of Weak Ties,' *American Journal of Sociology*, 78, 1973.

[21] B. Mintz and M. Schwartz, *The Power Structure of American Business*, University of Chicago Press, 1985. See also M. Mizruchi, *The American Corporate Network, 1900–74*, London, Sage, 1982.

[22] J. Scott and M. Hughes, *The Anatomy of Scottish Capital*, London, Croom Helm, 1980; J. Scott and C. Griff, *Directors of Industry*, Cambridge Polity Press, 1984; F.N. Stokman, R. Ziegler, and J. Scott, eds., *Networks of Corporate Power*, Cambridge, Polity Press, 1985; J. Scott, *Capitalist Property and Financial Power*, Brighton, Wheatsheaf, 1986.

Hegemony in the network of capital relations has been explored directly through an investigation of shareholding networks for 1976. The network of investment relations—the out-lines—showed clearly the dominance of the large insurance companies and pensions funds, with banks appearing far less prominently than they did in the network of interlocks. There was not, therefore, a one-to-one relationship between the two networks. Insurance companies and pensions funds tended to remain rather passive as investors, allowing bank directors to act on their behalf. Banks act as major brokers in the mobilisation of institutional capital and so acquire an importance at board level which is out of all proportion to their own assets and investments. Interlocks, therefore, become structured around the big banks, while shareholding relations are structured around the large institutions.

A recent and important work in the network analysis of intercorporate relations, which substantiates many of the above findings at an international level is *Levine's Atlas*.[23] Levine's book is modelled on geographical atlases and presents data on interlocking directorships across the world in 1980. Using multidimensional scaling, discussed below, Levine shows that the world network fell into five distinguishable sections: the national networks of France, Germany, Holland, and Switzerland, and a large 'English-speaking' network of enterprises from the United States, Canada, Britain, and South Africa.[24] The analysis shows clearly the strong 'regional' character of the network, though the overall map is dominated by a mass of enterprises from the north-eastern parts of the United States. Through using the index to the Atlas, it is possible to assess the 'network access' of particular directors and companies: the paths of connection can literally be traced through the Atlas as a way of assessing centrality. Levine presents little in the way of analysis and interpretation, but his Atlas represents the epitomé of the descriptive use of social network analysis.

Much of the research undertaken so far has been *descriptive* in intent. Researchers have been concerned to describe particular national networks and to compare them with others. But the introduction of the notion of 'primary interlocks' and the analysis of directed networks shows a recognition of the need to raise *explanatory* questions. Central to this has been the construction of a typology of interlocks. In my own research, my colleagues and I have distinguished a number of types of interlock. A *primary interlock*, as already seen, occurs where an executive director of one enterprise holds an outside directorship in another, and the line representing this interlock may be regarded as directed from the base company.[25] A *loose interlock* is undirected and weaker than a primary interlock, occurring when a person holds a non-executive position on two boards. There are two main types of loose interlock. An *induced interlock* exists simply as a consequence of the prior existence of two primary interlocks carried by one director: an executive of company A who holds outside directorships in companies B and C generates two primary interlocks (AB and AC) and one induced interlock (BC). A *secondary interlock*, on the other hand, is totally unconnected with primary interlocks and exists because a person with a base outside the corporate system holds two non-executive directorships.

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[23] J.H. Levine, *Levine's Atlas of Corporate Interlocks*, Two Volumes, New Hampshire, Worldnet, 1985. This has now been revised and is available on computer disc in IBM format.

[24] Problems of information meant that a Japanese section virtually disappeared from the data set.

[25] We also distinguish the 'tight interlock,' where a person holds an executive directorship in two enterprises, but this is of only limited importance in Britain. See Scott and Griff *op. cit*, pp. 24–6.

Each type of interlock has a different significance for corporate decision-making and a different relationship to capital and commercial relations. Primary interlocks and those secondary interlocks which are carried by non-executives with a firm base in a particular enterprise may be regarded as *institutional interlocks*, as they are most directly involved with institutionalised capital and commercial relations and are more likely to be both intense and durable. The purely secondary interlocks, on the other hand, can be seen as *liaison interlocks*, as they are most likely to be involved in the formation of loose liaisons and communities of interest.[26] This distinction seems clear from studies of 'reinstatement' patterns in interlock networks, which have shown that primary interlocks are far more likely to be reinstated following the death or retirement of the people who carry them. It has similarly been found that lines with a high multiplicity are more likely to be reinstated than those with low multiplicity.[27]

The move away from a purely descriptive to an explanatory approach is clear in the changing style of research in both Europe and the United States. More researchers are now treating interlocks as dependent or independent variables in relation to other social and economic processes. The various types of interlocks are no longer simply mapped in a descriptive way, though this remains a crucial first step. They are seen as the results of institutionalised capital relations, commercial transactions, and class-related processes. Interlocks are, in turn, consequential for such things as decision-making, executive career patterns, political campaign contributions, urban development, and upper class cohesion. In order to clarify some of the processes involved I have set out in Figure 3 a simplified model of business relations which I have found useful in my own research.[28]

The network of interlocking directorships, through which corporate information flows, can be seen as a 'superstructure' which is ultimately dependent upon the 'substructure' of financial hegemony. This dependence is mediated through patterns of control and corporate rule, upon which the network of interlocking directorships itself exercises a feedback relationship. Factors external to the business system which shape the network of interlocks and which are, in turn, influenced by this network relate mainly to processes of capitalist reproduction. These include kinship relations among members of the capitalist class, informal social contacts, educational attainments, and political influence. Similarly, class factors shape the substructure of financial hegemony, for example through upper class strategies of investment diversification.[29]

Though this model is over-simplified, it outlines, I believe, some of the main processes which structure the operations of the 'inner circle' of multiple directors. The particular mixture of interlock types found in the superstructure reflects the balance among the various factors mediating between it and the substructure. It is the structure of the inner circle itself, and the specific processes through which it is linked to the structure of financial hege-

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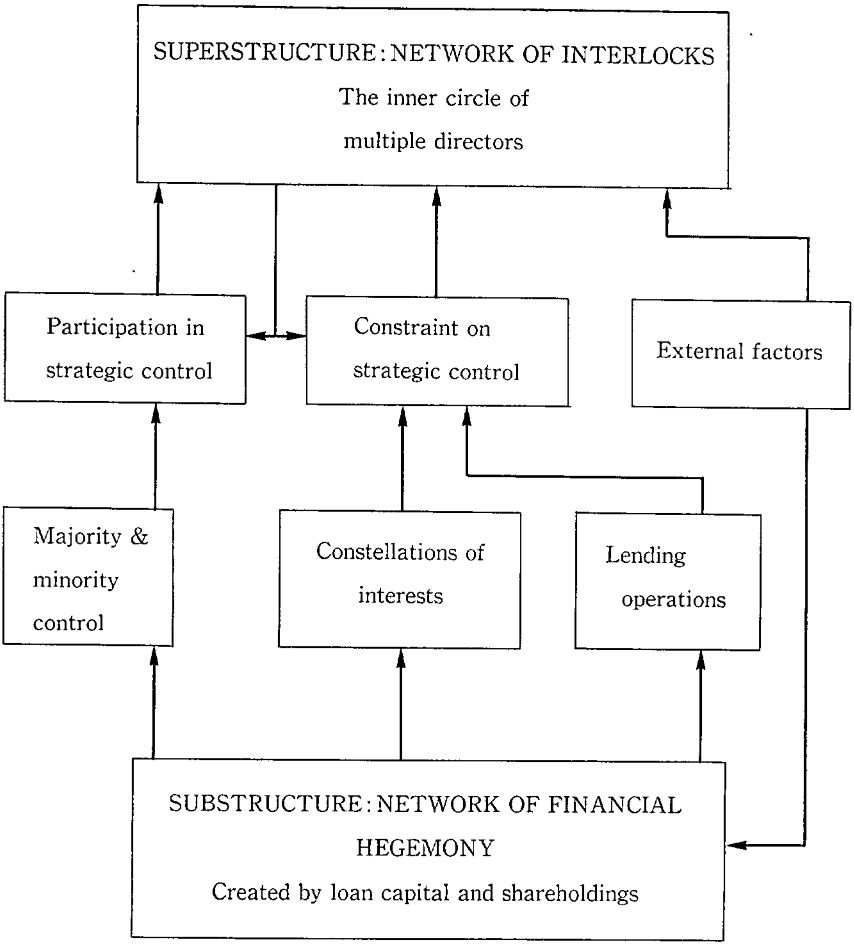
[26] See Scott and Griff, *op. cit.*, p. 180.

[27] See most recently, L.B. Stearns and M.S. Mizruchi, 'Broken Tie Reconstitution and the Functions of Interorganisational Interlocks,' *Administrative Science Quarterly*, 31, 1986.

[28] An earlier version of this model was set out in J. Scott, 'The Intercorporate Configuration: Substructure and Superstructure,' Paper presented to the Joint Sessions of Workshops, European Consortium for Political Research, Grenoble, 1978.

[29] See my paper 'Entrepreneurial Capital in Britain and Japan.' See also J. Scott, *The Upper Classes*, London, Macmillan, 1982.

FIGURE 3. THE INTERCORPORATE CONFIGURATION



mony, that explains the ways in which its members become involved in such matters as political contributions and urban development. The processes summarised in Figure 3 are also, of course, centrally involved in explaining the ways in which class reproduction occurs in advanced capitalist economies.

The Future of Network Analysis

I have outlined the application of social network analysis to the study of intercorporate relations, and have tried to illuminate both its power and its potential. It is now necessary to review some of the technical difficulties created by its reliance on graph theory.

The two major difficulties with graph theory are that it ignores conventional notions of distance and spatial arrangement, and that it is limited to two-dimensional representations of multidimensional social networks. These are, in fact, interrelated problems. The sociograms produced by graph theorists seek to give a clear visual representation of the social network to which they refer, and the aim is to arrange the points on the page in such a way that there are a minimal number of cross-overs among the lines. Thus, points are arranged and rearranged in terms of this aesthetic goal. Where the researcher aims also to keep all lines of an equal length, to represent the fact that they are regarded as representing equal 'distances,' it can prove impossible to achieve this with graphs of any size or complexity. This difficulty, however, has more than simply aesthetic implications, as it points to the limitations of two-dimensional representation.

A simple graph such as that of Figure 1 can easily be arranged in the two dimensions of a flat page: the arbitrary arrangement of the points was specifically designed to ensure that all lines were of equal length (the graph theoretic requirement) and that no line crossed any other (the aesthetic requirement). If more lines or additional points are added it would be necessary to re-arrange the points if these requirements are still to be met. But the time would soon come when one or both of the requirements would have to be abandoned. Consider the problem of drawing an extension to Figure 1 in which a new point, H, is connected to points B, C, E, and F. If the maintenance of lines of equal length is made the fundamental requirement, then a small amount of cross-over among these lines can be handled by making the sociogram into a three-dimensional model. That is, the principles of perspective drawing could be employed to imply that the figure on the page is actually a representation of a three dimensional structure. But even this will not suffice for graphs with many cross-overs, as these indicate that the network must be thought of as existing in four or more dimensions—and a perspective drawing cannot imply more than a third dimension.

It was for this reason that Levine has made use of multidimensional scaling (MDS). This is a set of procedures for converting data about the similarities or dissimilarities among objects into a non-arbitrary spatial arrangement, and is derived from the trigonometry and projection techniques used by map makers. Social relations between agents can be though of as bringing them 'closer' or 'further away' from one another in a spatial sense. The number and type of social relations, for example, can be converted into a measure of true distance. Instead of the arbitrary arrangement of points and lines which is produced in a graph-theoretic sociogram, MDS can use line distances in the graph to construct a meaningful configuration of points. Distance in such a configuration is represented directly by physical propinquity, and so the lines which connect the points, if these are included in the diagram, need not be of equal length. Levine, for example, used lines in an MDS model simply to indicate the patterns of connection, the 'routes' from one point to another.[30]

Ultimately, however, MDS suffers from some of the same limitations as graph theory. On a printed page only two dimensions can be used, and a maximum of three dimensions can be implied through perspective drawing. If more dimensions are required to produce a good fit, then the researcher must resort to some simplification: a three dimensional structure for example, can be represented as three separate two dimensional cross-sections, and a four dimensional structure can be represented as six two-dimensional cross-sections. Despite producing coordinates for *many* dimensions, therefore, MDS can display its models

[30] Levine *op. cit.*

only in *two* dimensions. One of the advantages of MDS—its ability to produce a non-arbitrary configuration of points—proves to be only a partial solution to the problems of graph theory. The structural properties of multidimensional configurations must be grasped and conceptualised in more abstract terms. The concepts of graph theory (such as centrality and density) provide intuitively understandable visual images which can be generalised to four or more dimensions, even if they cannot actually be directly visualised at this level of abstraction. Attempting to 'collapse' such representations into two dimensions results in considerable distortion, and the visual image of the structure can be lost. As a result, much of the power of the network metaphor is also lost.

The fundamental problem in applying graph theory in the social sciences, however, would seem to be the rooting of its concepts in the image of people and groups as 'points.' Applications of social network analysis have shown the limitations of this particular imagery. People and enterprises are themselves complex structures, and are intrinsically multidimensional. For this reason a number of social network analysts have begun to turn to a branch of mathematics, algebraic topology, which seems to offer a solution to this problem.

An influential approach in this area is Atkin's Q-analysis.[31] Atkin's basic assumption is that any object must be described not as a 'point' but as a geometrical figure called a 'simplex.' A simplex is defined by the number of dimensions which are required to specify the space in which it exists. Thus an object which is to be described, for the purpose in hand, by two attributes can, indeed, be represented in one dimension as a line connecting the points which represent these attributes. An object described in terms of three attributes, however must be represented as a triangle in two dimensions. The number of dimensions which are required increases with the number of attributes considered. While a company with three interlocks can be represented as a triangle, a company with four interlocks must be represented as a solid tetrahedron. People and groups, therefore, are to be pictured as solid pieces of multidimensional geometry which articulate with one another to form complex social structures. These structures—termed simplicial complexes—exist in a multidimensional space of the kind generated by MDS.

Q-analysis has, as yet, produced only a very few alternatives to the leading graph theoretical concepts, and it remains to be seen exactly how such notions as density and centrality might be translated into the more realistic language of Q-analysis. It is likely that future advance will require a greater accomodation between the competing approaches. Graph theory, which has for so long led the way, has increasingly come under challenge, and its dominance is no longer assured. But the day when the insights of graph theory and MDS will be incorporated into the framework of Q-analysis is still a long way off.

Conclusion

In this paper I have argued that social network analysis has a long history in sociology, but that it is only in the last thirty years that the metaphor of social network has been used in a theoretically rigorous way. Of major importance in stimulating this work, and in

[31] See in particular R.H. Atkin, *Mathematical Structure in Human Affairs*, London, Heinemann, 1974, and *idem.*, *Multidimensional Man*, Harmondsworth, Penguin, 1981.

encouraging the application of social network analysis to particular areas, has been an interest in formal mathematical models of networks. The choice of an appropriate model, however, is not a simple task. It depends upon the intellectual judgment of the researcher and the particular theoretical assumptions that are drawn upon. If those interested in social network analysis allow unfounded mathematical models to determine the nature of their work, then social network analysis will fail to have the impact on research which it deserves.

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