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4 Applications of network analysis

My outline of the key concepts and measures has, inevitably, been rather abstract and formal. I want now to make these ideas more concrete by illustrating their use in empirical studies that have applied them in relation to substantive sociological issues. I will do this through a consideration of three of the areas that have made the most extensive use of social network analysis. First, I will look at work on the diffusion of ideas and practices through social networks, showing how the structure of a network can shape the flow of information and resources. Secondly, I look at studies of the scholarly networks created through the citation of scientific papers, training at graduate research centres, and participation in scientific conferences and workshops. I will show that these studies have produced mappings of the intellectual space within which scientific production takes place. Thirdly, I will examine studies of corporate power through investigations of interlocking directorships. I will explore issues of centrality and its relation to corporate power and the existence of bank-centred cliques and clusters.

Diffusion and the flow of information and resources

Diffusion studies are concerned with how the flow of information and attitudes about new practices and techniques are shaped by the structures of the networks in which intercommunicating individuals are involved. The earliest writer to highlight the need to investigate diffusion in this way was the French lawyer and criminologist Gabriel Tarde, who saw imitation as the basic psychological mechanism responsible for this diffusion. In his *Laws of Imitation* (Tarde 1890), he set out an account of the factors that constrain imitation and explored the consequences of these for the spread of new ideas and technical innovations. Interaction, he argued, is grounded in the natural tendency for individuals to imitate the behaviour of those who are psychologically close to them and with whom they identify. Thus, interaction is necessarily a process in which individuals behave, intentionally or unintentionally, in ways that those they encounter may either take up or ignore. Innovations made by one individual are, therefore, subject to selective retention and replication, much as genetic variations are selectively replicated in Darwinian theory.

Tarde saw chains of such processes of imitation as the basis on which 'rays' or 'waves' of innovation spread from focal innovators to permeate a whole network. As more and more individuals adopt the innovation, it is able to spread in multiple and intersecting waves that are constrained in their movement by the paths and blockages inherent in a given pattern of social connections. Cultural transmission is not, therefore, a simple and unproblematic process but is complex in both its causation and

its consequences. One of Tarde's principal conclusions was that the rate at which an innovation spreads can be described in an 'S' curve in which the number of those who adopt an innovation increases slowly at first but then takes off exponentially until it again slows down at the point where few potential adopters remain. Tarde highlighted the importance of those who are regarded as exemplars or role models. These are the people that individuals look up to and respect and who are especially likely to be imitated. These individuals are the influential 'opinion leaders' in the process of diffusion.

Tarde's suggestions had some influence in studies of political communication and opinion formation, but he had little wider impact until the 1940s. It was then that the full range of his ideas began to be appreciated in a small number of studies in rural sociology. The most important of these studies was that of Ryan and Gross (1943), who studied the release of a strain of hybrid corn to farmers in Iowa. Tracking its adoption from its initial release in 1928, they showed how it eventually revolutionised farming techniques in the State. The hybrid seed was developed by research scientists at Iowa State University and was promoted through the advertising and sales campaigns of the seed companies. Take-up of the corn, however, depended on the massive job of persuading farmers to purchase new seed each year, rather than the traditional practice of relying on a saving of seed corn from the current year's crop. The new seed would be successful only if farmers could be persuaded to make a substantial and continuing investment in the purchase of seed. Successful adoption of the innovation therefore required a significant change in behaviour.

Ryan and Gross showed that the rate of adoption over the period of the study followed the 'S' curve suggested by Tarde. Although sales publicity could make most farmers aware of the new products, there were initially only a small number of early adopters. Most of those who eventually used the new corn did so only after discussion with neighbouring farmers who could persuade them that using the new corn was worthwhile. Persuasion through discussion, rather than simple imitation, was the key to adoption, and people were especially likely to be persuaded by the early adopting opinion leaders whose views they valued. When a number of neighbours had adopted it and advocated its use, other farmers were very likely to take it up. Thus, the initial spread was slow until there were sufficient adoptees for many farmers to have at least one adopter in their neighbourhoods. Take-up then accelerated rapidly as the number of new adopters increased across the State. Eventually, however, a point was reached at which few non-adopting farmers remained and the rate of adoption slowed down.

Only in the 1960s was there any advance on this work. James Coleman and his associates (1966) undertook a study of the introduction of the new antibiotic Tetracycline (referred to in the study as 'Gammanym') and of its adoption by general practitioners. Though unaware of the earlier work of Ryan and Gross, they also discovered both that the pattern of adoption followed an 'S' curve and that the opinion leaders were of key importance in this process. Coleman also found that those with the highest neighbourhood degrees, as measured by hospital affiliation, attendance at staff meetings, and sharing an office with other doctors, were more likely to be early innovators and

were most likely to be named as sources of information or as friends by other doctors. These were the people who became early innovators through a 'chain reaction' or contagion effect that ran through their well-connected neighbourhoods. They subsequently became influential contacts working through what Granovetter was to term the 'weak ties' and so were responsible for the spread of the innovation to other parts of the network where local opinion leaders sponsored its take up and influenced others in their area.

A few years earlier than the Coleman study, Everett Rogers (1962) had undertaken a systematic review of research on innovation and had drawn this together into a systematic review of the area. Initially publishing this work in 1963, it took its definitive form in the Third Edition of 1983 and appeared in its Fifth Edition in 2003. Rogers showed that the overall inclusiveness, fragmentation, and density of interpersonal networks determine the extent of exposure people have to new ideas and ways of behaving. The relative location of individuals within this network—their peripherality, the size of their neighbourhood, their involvement in cliques and clusters—determine the extent and salience of their exposure. He highlighted a social process in which there were distinct phases of knowledge, persuasion, and decision: individuals who adopt an innovation must become aware of it, form an attitude towards it, and decide to adopt it.

Rogers argued that individuals are likely to become aware of new ideas that meet their needs or interests as a result of their exposure to the information that flows through a social structure. While people may sometimes actively search out innovations, they are more typically dependent on formal and informal

messages that come to them through their regular channels of communication. This is how they may even be made aware of new products and services that they did not previously realise they 'needed'. Those who acquire knowledge early—the 'early knowers'—are those who have a large number of social contacts and a wide sphere of interaction through which they can reach them. Mass media channels are, however, of greatest importance in the knowledge phase of the diffusion process.

Rogers rejected the dubious psychological assumption of a natural propensity to imitate. An idea is taken up only if individuals are persuaded to act on their knowledge: they must develop a favourable attitude towards it through assessing its likely pros and cons. This is most likely to occur when a person is aware that others who he or she has cause to trust are considering it or have already adopted it. The more of a person's contacts that are in this state, the more likely is he or she to form a favourable attitude. It is only at this point that an explicit decision to adopt or not to adopt is made, with collective pressure being especially important in bringing about conformity with the evolving decisions within a person's sphere of contacts. The more people an individual is aware of who have made a decision to adopt, the more likely is he or she to follow suit.

Within this process a key role is played by the opinion leaders that occupy central positions within networks. They are the key determinants of the rate of adoption because their position in their social network makes them critical to the flow of information through it—making them influential for a large number of people—and because their respected status means that their opinions carry a great deal of weight (which can be represented

by the intensity of the lines connecting them to others). Thus, diffusion must be studied in relation to the structures of the neighbourhoods in which people are embedded. The three-fold process of knowledge, persuasion, and decision proceeds iteratively and cyclically, such that the critical mass of adopters builds up and larger and larger numbers of individuals are exposed to the pressures that encourage them to adopt an innovation. This explains how the observed exponential shape of the 'S' curve is a direct consequence of this ongoing process.

This approach to innovation has been applied in a number of recent studies. In an investigation of the spread of Christianity, Rodney Stark (1996) asks how it was that a tiny and obscure Messianic movement on the edge of the Roman Empire with a maximum of around 1000 adherents in 40AD was able to dislodge pagan beliefs and grow to more than 33 million adherents by 350AD, the year that the Emperor Constantine converted to Christianity and allowed the religion to become the dominant faith of the western world. The annual growth rate for contemporary religious movements is around 40 per cent and Stark assumed this to be the case for early Christianity. Using this figure, he showed that a constant and realistic annual growth rate does, indeed, produce an exponential absolute growth on the scale suggested by the evidence. The growth of Christianity followed an 'S' curve, with the crucial upturn occurring between 250AD and 300AD.

In order to explain this pattern of growth, Stark drew on the idea of differential association. Conversion to a new religious group, he argued, is more likely when people have stronger attachments to existing members than they do to non-members. It is the balance of attachments rather than

doctrinal commitment, that explains the propensity to listen, join, and *then* become committed. Thus, the basis for the growth of a religious movement is to be found in the social networks of direct and intimate interpersonal attachments. Individuals are more likely to respond positively to those with whom they are close and share attitudes and outlook. When recruited, they are especially likely to bring in or ease the recruitment of their immediate family members and intimate associates. Successful religious movements are those that avoid becoming 'closed' and are able to reach outsiders, especially through their weak ties.

Stark showed that early recruitment to Christianity occurred through the networks of the Hellenised Jews, who were already somewhat detached from Palestinian Judaism but were also marginal to Greek society itself. It was through their networks of mutual support and social solidarity that Christianity was able to grow through the Synagogue communities. Thus, conversion in the earliest years was most marked in such cities as Caesarea, Damascus, Antioch, Corinth, Ephesus, and Rome. These were the larger cities of the Graeco-Roman world, many being the diaspora cities of Asia Minor, where Jews constituted a large enough group to form a 'critical mass' for conversion. These cities were, however, relatively disorganised, as they were newly re-established and with colonial and migrant populations. They were also relatively 'open cities' in which many people would have had weak ties to other such cities. It was here that Christianity had its greatest appeal as providing an answer to the prevalence of deprivation and suffering.

Oliver and her colleagues (Oliver *et al.* 1985; 1988b; Oliver *et al.* 1988a; Marwell and Oliver 1993) have developed an approach

that extends the standard model of diffusion to the intermittent and cyclical processes that allow the formation or strengthening of social movements and the organisations that carry their ideas forward in concerted joint action and collective protest. Following Roger Gould (1993), they argue that ‘closed’ organisations—those that are relatively self-contained clusters of related individuals formed into overlapping cliques—can develop and sustain the solidarity required for joint action far better than can ‘open’ organisations. Thus, a cell structure may be an appropriate organisational form for a radical political group. They show also that the diffusion processes in social movements can generate periodic ‘spikes’ of activity and a cyclic rise and fall in protest activity, especially where the extent of diffusion is strongly influenced by news media coverage (Oliver and Myers 2003). Gould himself (1995) applied similar ideas in his own study of the formation of popular protest movements in nineteenth century Paris.

These diffusion ideas were brought into the mainstream of formal social network analysis by Ronald Burt (1987; 2005), who connected social influence with analyses of social capital. Tom Valente (1995) has usefully summarised these arguments in a formal extension of Rogers’s argument.

Citation studies and the sociology of science

A long tradition of research has outlined the use of publication patterns and, especially, citation patterns, to map forms of social organisation in science. Building on suggestive research into the

importance of 'scientific communities' and groups of scientists in the formulation and growth of scientific knowledge (Kuhn 1962; Price 1963), Diana Crane (1972) was one of the first to use ideas from diffusion research to explore scientific innovation, the formation of scientific specialisms, and their basis in processes of recruitment, promotion, and co-authorship. While she used sociometric measures, derived from Coleman's software, she concentrated on diffusion and scientific growth and did not report her findings in what is now standard sociometric format. Nevertheless, she produced a pioneering study that set the baseline for later investigations into scientific networks.

Crane showed that the growth of knowledge within a scientific specialism exhibits the characteristic 'S' curve of diffusion and asked what it is about scientific communities that can explain this. She pursued this question through a study of two specialisms: the rural sociologists concerned with agricultural innovation and mathematical work on finite groups. Authors of published papers in each of these areas were the basis for a mapping of networks of the scientific relations resulting from involvement in informal discussions, published collaborations (co-authorship), relations with teachers, and the influence of colleges on the selection of research problems and methods. Crane found a close correspondence between the structures found in each of these forms of relationship: between two thirds and three quarters of all authors were connected into a large, low density component, and up to a half of the authors reported that they thought these relationships were important in their research. They formed a 'circle', as defined by Kadushin, in that they were loosely bounded structures of communication

and awareness whose members are geographically dispersed and so are largely engaged in correspondence, co-publication, and intermittent and infrequent face-to-face discussion. A majority of the members of each specialism were, directly or, more typically, indirectly in contact with a majority of the other members.

Groups of associates were identified on the basis of those who were named as collaborators in scientific projects. These were seen as the 'invisible colleges', the virtual laboratories and work groups through which research is organised. The number of publications produced by an individual was found to be the basis of the longevity of their career as a member of the specialism and of their ability, therefore, to influence norms and practices within it. Isolates and members of small cliques were less likely to be regarded as influential within the specialism. Successful specialisms were those with dominant—central—individuals who acted as the 'leaders' who trained or collaborated with a large proportion of other members. Crane concluded that the peripheral and isolated members of scientific communities must rely on formal mechanisms of communication rather than the informal networks of communication and so are less able to keep up-to-date and are less likely to make significant contributions to their field.

Shortly after Crane's study an exploration into the structure of theoretical debates in American sociology was undertaken by Nicholas Mullins (1973), using somewhat more systematic network methods. Mullins saw theoretical 'schools' of thought as invisible colleges formed from relations of communication, co-authorship, apprenticeship, and colleagueship. A new theoretical orientation, he argued, develops from an initial

loose stage in which work is carried out by isolated theorists at a number of different universities, through a 'network stage' in which key publications become the focus of work by people in frequent communication with each other, and a 'cluster stage' in which groups of students and colleagues form around the key specialists in a small number of universities. Finally, a theoretical area may reach the 'speciality stage' in which students who have begun independent careers carry the work to a larger number of institutions and build up their own links to new students and junior co-authors.

Theoretical groups were identified from a reading of the literature and discussion with colleagues, and Mullins undertook separate network analyses for each of the eight areas that he chose to study. Data on training and careers were collected from interviews and from information included in directories, footnotes, and other published sources. Data on co-authorship came from the indices of the *American Journal of Sociology* and the *American Sociological Review*, together with the actual books and articles produced.

Mullins's first report was on what he called 'Standard American Sociology'; perhaps the most successful of all theoretical specialisms. This grew from the initial suggestions of Parsons (1937) to become the mainstream of American sociology through the 1950s and 1960s. This entered its network stage in 1935, with a particular focus on Harvard and Columbia, and entered its cluster stage a decade later. Under the intellectual leadership of Parsons, a cluster of 13–15 students, teachers, and researchers forged the central elements of the structural-functional approach. From 1951 it expanded its influence at other universities and

established itself as the dominant theoretical orientation in the United States.

Turning to the secondary tradition of symbolic interactionism that emerged at Chicago and reached its specialty stage in 1952, Mullins shows this to be an extensive but somewhat looser network of researchers. The network of co-authorship included five components, the largest including thirty-seven members. Central participants were Ernest Burgess, in the earliest stages, and then Anselm Strauss, Howard Becker, and Everett Hughes. This core group of symbolic interactionists, like two of the smaller components were connected to authors from within the structural functionalist group, and Mullins took this and the fragmentation of the network as indicators of a relatively loose structure.

This structure can be contrasted with ethnomethodology, which emerged around Harold Garfinkel's seminars at UCLA in the mid-1950s, expanded through Berkeley and Santa Barbara, and began a diffusion of influence as a specialism in 1971. The group was much smaller than the structural-functional group and the network of the invisible college was far more fragmented. The co-authorship network, for example, comprised seven components, three of which were simply pairs. The largest component included nine authors and had its focus in Aaron Cicourel, who co-authored with all of the other eight members. Indeed, without Cicourel, the large component would have shrunk to a triad.

A particularly influential use of this approach to intellectual development was Randall Collins's study in *The Sociology of Philosophers* (2000), in which he provided a theoretical rationale for network studies. Collins started out from the assumption

that individual thought in philosophy and science can be understood as the internalisation and coalescence of ideas circulating through the networks in which scientists and philosophers are involved. An intellectual may work physically alone, as a lone scholar, but always within a social context that means that he or she is never mentally alone. Thus, 'Thinking is a conversation with imaginary audiences' (ibid., 52). Collins therefore argued for the need to study intellectual activity through what have been called the collaborative circles (Farrell 2001) and other networks of association through which cooperation, influence, and argument take place.

This provides the rationale for selecting the particular relations that have been studied in the investigations of the invisible colleges. Ideas are communicated face-to-face in meetings, congresses, lectures, and workshops, through systematic and informal training, and in written texts such as articles, monographs, textbooks, working papers, and so on. Changes in communications technologies supplement these relations with new forms of e-mail and on-line communication. These various networks of linkage are embedded within 'organisational bases' that make communication possible: systems of higher education, publishing, retailing, and professional organisation that sustain their reproduction as an intellectual way of life. Studying such processes over a period of more than two thousand years, from Classical Greece to the present day, involves considerable problems of data consistency and reliability. Collins uses much qualitative and, it must be admitted, impressionistic data, aiming to compile as much source material as possible on intellectual apprenticeship and teaching, publication, recruitment and

promotion, and debate, and attempting to document negative, conflict relations as well as the more positive ones. Collins's approach depends upon the *ad hoc* discovery of personal links and on his ability to infer intellectual lineages from his knowledge of the philosophical positions.

Collins's work can best be illustrated by taking his analysis of the period from 1765 to 1935: the period since Kant and in which the universities underwent a radical transition from a patronage system to the contemporary system of research universities (Collins 2000: Chapters 12 and 13). This was the period in which the influence of idealist philosophers who had broken with theological ideas spread with the German model of the university and gave birth to a whole swathe of new philosophies. Collins traces the massively influential links from Kant to his pupil Herder and to his close friend Goethe and then from these to Fichte, who initiated a fully idealist system and was a central figure in influencing Schelling, Schopenhauer, and Hegel. Conflict between Hegel and Schopenhauer followed a split in the network that presaged a decline in the influence of Schopenhauer at the same time as a massive growth in the influence of Hegel. Hegel's influence grew with the prominence of Berlin in the German university system and was the basis for expansion abroad.

In Britain, Collins argues that university reform was marked by the growth of idealism into a philosophical culture hitherto dominated by the utilitarianism of non-professional philosophers. Developing through Jowett, Green, and Bradley at Oxford, it became the dominant approach to philosophy through the interlinked careers of their students Caird, Seth, and Bosanquet. Critical attacks from Bradley on other philosophers fragmented

the expanding system into a number of distinct clusters of ideas and individuals: the evolutionary and positivistic thought of Huxley, Lewes, and Eliot, and, through the central position of Russell, the soon-to-be-dominant school of analytical philosophy. The latter included Russell's teacher Whitehead, Moore, Keynes, and members of the tightly knit friendship clique of the Bloomsbury Group, and it influenced the independent line taken by Russell's student Wittgenstein.

Collins's work, then, provides a clear theoretical basis for the use of citation and other data on scientific linkages to map intellectual networks. His own work, inevitably, faced data problems that meant he needed to take a more impressionistic approach to data analysis than had been the case in the studies by Crane and even by Mullins. However, recent work by Howard White has brought such work into the mainstream of social network analysis and established a clear basis for both theoretical and methodological advance.

White and his colleagues (2004) studied the 'Globenet' research group, a pseudonym for a small international and interdisciplinary research group. The researchers aimed to investigate both the social and intellectual structures of the Globenet group and so looked at citation practices among members, together with such social ties as friendship, research contacts, and advice-seeking, and they also undertook some interviews. The core of their analysis, however, concerned citation patterns. Taking four time periods from pre-1989 up to 2000, they looked at the changing patterns of both 'intercitation' (the citation of each other) and of co-citation (joint citation of the same source).

The study found that although three quarters of members did not cite each other, there was a growth in the overall level of intercitation over the whole period. Similarly, the density of the network increased substantially. The distribution of intercitations was found to be scale free, a small number of researchers accounting for a large proportion of all citations. Those who engaged in mutual citation tended to rate each other as 'friends', were involved in direct collaboration, worked in the same discipline, and knew each other from before Globenet was set up. The editors of a collectively produced book were central to the network and also played a leadership role within it. It was found that they had especially high levels of out-citation, showing that they took seriously the need to solidify the group by affirming its collective identity in their own publications.

Co-citation patterns tended to reflect disciplinary differences, though some individuals appeared as 'interdisciplinary linchpins' (White *et al.* 2004: 120). The extent of cross-disciplinary citation increased as the project developed. Intercitation increased with the total amount of scholarly communication and with communication outside of meetings. It correlated with written (and e-mail) communication, but not with telephone use, and it correlated negatively with face-to-face scholarly communication through attendance at the same conferences and workshops.

White and his colleagues concluded that citation patterns reflect both the social structure of the research group and its intellectual consolidation. Over and above the effects of group leadership, people tended to cite each other's work when they were better acquainted with each other. The development of the Globenet project increased the tendency of its members to

cite the work of other members. It was also found, however, that there was a tendency for citation to reflect intellectual affinities of theory or method.

The possibilities of using systematic network methods are vividly illustrated in work by Moody and Light (2006), who used citation data to investigate the overall structure of sociology as a discipline within the social sciences. They look at the co-citation of social science journals in order to discover how similar any two journals are in their contents in terms of citations to them by papers in other journals. The raw data on similarities among 1,657 journals were mapped into a multidimensional space and the authors devised a way of drawing contour lines that surround journals with specified levels of similarity. Peaks in the contour map, they argue, can be seen as 'discipline'-specific clusters of journals.

The mapping produced by Moody and Light (2006: 71, Fig 1) shows strong and closely linked clusters for law and economics, closely connected to similar clusters for political science. On the immediately opposite side of the map is the strong cluster of psychology journals. Spread between law and psychology are a series of lower peaks corresponding to management and organisational behaviour. In the opposite direction, the 'foothills' from psychology trail through education and social work. Sociology appeared as a moderately high peak in the dead-centre of the map, while geography and anthropology appeared as low foothills between sociology and political science. The height of the peaks in the Moody and Light map correspond to the sharpness of the boundaries defining a journal's authors, and hence the boundaries of a discipline. Sociology, they found, is not so

strongly inwardly influenced as psychology or economics, tending to draw on other disciplines and to contribute to them. By contrast with economics, sociology has no clear structure of central or core journals.

From this mapping of social science, they turn to a detailed mapping of sociology itself, tracing changes in journal connections over the period 1970 to 1990. This time they looked at the topics discussed in articles in order to investigate the state of sociological discourse. Their analysis is, therefore, a conceptual network of journal content based on a frequency count of words. They show that in the 1970s, there were strong clusters for community, education, race, and culture, with each of these surrounded by looser groupings of topics. By the 1990s this had completely changed, with strong areas being health, family, gender, and science-teaching. Sex as a topic of study in sociology journals had grown considerably and was linked to a new large peak of articles on AIDS-HIV. All other areas were much looser than before. Finally, by the late 1990s, the AIDS peak had shrunk back somewhat and was matched by peaks on health care, welfare, language, and stratification, together with interlinked peaks on science, technology, and the sociology of sociology.

Sociology, then, Moody and Light found to be in constant interchange with neighbouring 'stronger' disciplines, and with its specialisms restructuring in relation to trends in the outside world. There is a constant shift in *topics* of study, although the body of sociologists producing these may be more constant and cohesive.

Interlocking directorships and corporate power

Studies on the role of company directors have a long history in social science, though its immediate origins were in journalistic and political investigations of the concentration and abuse of economic power. Directorships have long been seen as sources of power. A directorship in a company, or corporation, is a position at the top of a company that confers legal authority over its assets and employees on its occupant. Holding directorships in two or more companies proportionately increases the power of the individual concerned. Thus, tabulations of the number and distribution of directorships has been seen as a way of charting the degree to which corporate power is concentrated in the hands of a small number of individuals or families.

The earliest studies of this power were those of Otto Jeidels and John Hobson. Jeidels, a member of a Frankfurt banking family who became a leading investment banker and himself the holder of multiple directorships, published a study of board-level relationships between banks and heavy industry in Germany (Jeidels 1905). He tabulated the total numbers of directorships held by directors of each of the big six banks and traced whether these directorships were held by bankers or industrialists and so could be assigned a direction: from banks to industry or *vice versa*. His report tabulated what he described as a 'community of interests' among the directors at the heart of the German economy. Hobson, a labour activist and journalist, drew on his experiences reporting the Boer War in South Africa to add a section on corporate power to the Second Edition of his study of *The Evolution of Modern Capitalism* (Hobson 1906). Taking

up popular comment on the 'Randlords', the leading gold and diamond producers of South Africa, he tabulated the directorships held and their formation into an 'inner ring' of finance. The arguments of Jeidels and Hobson were important influences on Marxist work by Rudolf Hilferding (1910) and Vladimir Lenin (1917), who documented the emergence of a dominant group of 'finance capitalists' who had become the leading elements in the various financial groups that pursued strategies of imperial expansion across the globe.

Hobson, however, had gone beyond numerical tabulation and had produced a diagrammatic representation of the inner ring. Most probably inspired by radical metaphors of the 'webs' of influence and the 'tentacles' of large business groups, Hobson drew a schematic and simplified diagram in which circles representing financial groups were connected through a mesh of criss-crossing lines, to numerous industrial ventures. Hobson's suggestive innovation was taken up by a US congressional subcommittee enquiry into the monopolistic power of the so-called Money Trust (US Congress 1913). The report not only tabulated the distribution of directorships but also produced large charts in which the connections among the large companies and corporate groups were laid out as maps of corporate power.

The congressional report introduced, or at least popularised, the term 'interlocking' directorships. When one individual holds a board-level position in two companies, the two boards, or directorates, are connected. This 'interlock' is a social relation between the two companies and was seen as a channel of communication and potential influence between business

entities that the law and economic theory regard as separate sovereign bodies. Thus, numerical tabulations of directorships can be seen as reports of the quantitative significance of this structure of power. This assumption became the basis on which many later investigations by academics, governmental bodies, and others aimed to investigate the monopolistic powers of top bankers and industrialists regarded as the elite of financial controllers.

A key theme in this research was the attempt to discover and document the particular financial groups that lay at the heart of modern economies. Variouslly described as 'interest groups' or 'empires' of finance, these groups were not, however, always defined in clear or strict sociometric terms as cliques or components. They were seen as groups of companies subject to common control, but no precise measure of control and hence of the boundaries of this control were specified. The resulting indeterminacy is apparent in the fact that studies of the same economy at similar times have reported different numbers of financial groups. Thus, Marxist economist Paul Sweezy (1939) undertook an investigation for the National Resources Committee of the US Congress in which he documented eight such groups associated with various of the leading investment banks. By the 1950s and 1960s, estimates of group structure varied widely: Perlo reported eight groups but Dooley (1969) reported 15 and Menshikov (1969) reported 22.

The first study of interlocks to introduce proper techniques of social network analysis was that of Warner and Unwalla (1967). Drawing on ideas that had been developing since Warner had himself introduced the idea of the 'clique', Warner and Unwalla

described the structure of the US economy as organised around a 'hub' of finance companies with 'spokes' that radiate out into the wider economy. While this remained a metaphorical description, they did report its structure through tabulations of the 'direction' that could be attached to an interlock. When a director holds a full-time executive position within a company, which can thus be regarded as his or her principal business interest, the interlocks created can be seen as an outgoing relation from the base company. From the standpoint of other companies it is an incoming relation from the base company. These two types of interlock, Warner and Unwalla argued, can have a different significance for the companies involved. Later research has distinguished these 'primary interlocks' from the 'induced interlocks' that result among the companies on which the executive sits as a non-executive director and the 'secondary interlocks' that are created by directors who are completely without executive positions (Stokman *et al.* 1985).

Over the following years, a number of studies have used more rigorous sociometric ideas. Levine (1972) and Bearden *et al.* (1975) used the new ideas being produced by Harrison White and his colleagues and students to measure centrality in corporate networks and the function of the cliques and clusters formed around central companies. At the same time, Mokken and Stokman oversaw an investigation of the Dutch economy (Helmens and others 1975) and put together a large international research group to study interlock patterns in ten countries (Stokman *et al.* 1985). Bearden and his associates used a measure of centrality based on the idea of closeness and that took account of direction. They documented the existence of

an extensive national network of predominantly 'weak' ties (secondary and induced interlocks) within which could be found more intensely-linked clusters based on the 'strong' ties (primary interlocks) created by executives. The clusters were organised around focal banks and these bank-centred groups were loosely integrated into an extensive national network.

The group led by Mokken and Stokman used the concept of the component to identify any clearly bounded corporate groups that there may be in the Dutch economy. An analysis of undirected interlocks found a single large component containing 84 companies. A breakdown into subgroups on the basis of their densities disclosed a smaller 'core' group and a surrounding periphery. While the core of 17 central companies had a density of 0.76, the density of the whole network was just 0.19. Thus, they argued, the 17 central companies formed a densely connected group of financial companies with influence over the other 67 companies in the large component.

Scott and Griff (1984) used component analysis to show that the largest 250 companies in Britain in 1976 were formed into one large component of 185 and just two smaller components. An analysis based on the value of the lines—the number of directors in common between two companies—showed the existence of many more components, the largest containing just 17 companies. A major part of their analysis, however, concerns cliques identifiable in the network of interlocks carried by executives. The 156 companies in the large component of the network of such primary interlocks contained eight 2-cliques that varied in size from 10 to 15. The central points within each clique were largely taken by banks or insurance companies.

The British network of 1976, therefore, comprised a structure of overlapping bank-centred spheres of influence. It was within and through these spheres that the bank and industry executives who dominated their boards were able to exercise a degree of control and influence over the companies and it was through the overlapping relations of the larger structure of the weak ties that they could ensure a degree of coordination across the economy as a whole.

Levine (1972) recognised the problems involved in drawing sociograms for large networks and so used multidimensional scaling to chart structures of centrality and influence among 70 industrial companies linked to the 14 largest banks of 1966. A three-dimensional representation showed that these interlocks had a regional pattern, that banks were the most central companies, and that the third dimension sharply separated the banks from the industrials. Levine explored this third dimension further using cartographic techniques. Banks, he argued, stood at the centres of clusters of influence and these clusters could be mapped as discrete spaces on the surface of a sphere.

This remarkable burst of research between 1972 and 1985 contained all the key themes to emerge in the social network analysis of corporate interlocks. Subsequent studies have applied similar ideas to different economies, or have taken longitudinal approaches to changes in corporate interlocks over time. One area of strong development, however, has been the attention accorded to transnational networks. Meindert Fennema (1982) had undertaken an analysis of international links and had showed the persistence of national and regional—generally language-based—clusterings. The growing globalisation of economic

relationships, however, has led many to investigate whether such nation-state-centred structures have disappeared. David Smith and Doug White (Smith and White 1992) pointed the way with a study of networks of international trading patterns that used blockmodelling to document the existence of trading blocks and their relationship to Wallerstein's world-system categories of core, semi-periphery, and periphery. This kind of approach was taken up in interlock studies by Fennema and Carroll (2002) to investigate the formation and structure of a transnational business community of people with attenuated links to particular national economies.

Further reading

Rogers, Everett 1962. *Diffusion of Innovations*, 5th Edition. New York: Free Press, 2003. The definitive overview of diffusion studies and approaches.

Coleman, James S., Katz, E. and Menzel, H. 1966. *Medical Innovation: A Diffusion Study*. New York: Bobbs-Merrill. Remains a classic study in the application of diffusion methods.

White, Howard D. 2011. 'Scientific and scholarly networks. In *The Sage Handbook of Social Network Analysis*, John Scott and Peter J. Carrington, eds. London: Sage Publications. A clear and definitive account of citation and bibliometric methods.

- Mullins, Nicholas C. 1973. *Theories and Theory Groups in American Sociology*. New York: Harper and Row. An early example of work on scientific networks that is especially accessible for students of sociology.
- Pennings, Johannes 1980. *Interlocking Directorates*. San Francisco: Jossey-Bass. Chapters 1 and 2 provide one of the few general accounts of this methodology for studying corporate power.
- Carroll, William K. 2004. *Corporate Power in a Globalizing World. A Study in Elite Social Organization*. Ontario: Oxford University Press. A powerful recent example of work in this area.

Applications of social network analysis in other areas and specialisms include:

- Wellman, Barry 1979. 'The community question: the intimate networks of East Yorkers'. *American Journal of Sociology* 84: 1201–31. An important and influential report on community structure and personal networks.
- Werbner, Pnina 1990. *The Migration Process: Capital, Gifts and Offerings among British Pakistanis*. Oxford: Berg Publishers. Uses blockmodelling techniques to investigate migration patterns.
- Gould, Roger V. 1995. *Insurgent Identities: Class, Community and Protest in Paris from 1848 to the Commune*. Chicago: University of Chicago Press. Uses network techniques to investigate class formation and solidarity.
- Bearman, Peter S. 1993. *Relations into Rhetorics: Local Elite Social Structure in Norfolk, England: 1540–1640*. Rutgers: Rutgers University Press. An historical study using legal records to investigate aristocratic class relations.

A range of specialised papers can be found in:

Scott, John and Carrington, Peter, eds 2011. *The Sage Handbook of Social Network Analysis*, London: Sage Publications. Section 2 includes Chapters reviewing work on social support, online communities, policy networks, terrorist networks, criminal networks, cultural networks, and many other topics.

Scott, John ed. 2002 *Social Networks: Critical Concept*, Four Volumes. London: Routledge. A collection of classic sources. Volumes 2 and 3 cover family and community; Volume 3 covers corporate power and economic structure, and Volume 4 covers politics, protest, and policy networks.