SOCIAL INTERACTION & ORGANISATIONAL CHANGE: AN ANALYTICAL REVIEW OF INNOVATION NETWORKS

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RP9934
November 1999

ISBN No 1 85449 339 6

Abstract

In recent years the term innovation network has been utilised by writers from a number of disciplinary areas including actor network theory, regional networks, policy networks and supply chain management. Our own interest in the topic is primarily concerned with the way in which business organisations manage the innovation process. Therefore, we carry out an analytical review of literature which concentrates on the way in which networks (internal and external) contribute to the effective management of innovation. Fifty papers are categorised in terms of the underlying theoretical perspective, the methodological approach, the nature of the analysis and the sample size. We conclude that too many contributions to the literature are little more than crude empiricism and suggest that our own approach based on social network analysis provides a deeper understanding of the way in which 'networking' contributes to innovatory activity.

Introduction

It was recently pointed out that there has been an impressive accumulation of studies focusing on organizational relations and networks over the last ten years (Oliver and Ebers, 1998:549; Grandori and Soda, 1995). At the same time, the authors suggest that this work has not resulted in an accumulation of knowledge nor of conceptual consolidation. By examining 158 articles on networks from four leading journals Oliver and Ebers posit that there are three core theoretical approaches or 'structural beacons' which provide orientation: resource dependency (Pfeffer and Salancik, 1978), political power (Zald, 1970) and 'network approaches' (Powell, 1990; Burt, 1992). It is claimed that this research demonstrates a 'central paradigm' which 'has tended to view inter-organizational networking as a response to dependencies among organizations that aims at enhancing the power and control of the networking organizations in order to foster their success' (Oliver and Ebers, 1998:565). Methodological approaches are dominated by cross-sectional, quantitative empirical studies carried out at the organisational level. Interestingly, despite this adherence to positivistic approaches 'there seems to be no clear consensus in the field on which outcomes are of central interest to research' (Oliver and Ebers, 1998:566). Perhaps not surprisingly given the positivistic orientation of most studies, the authors point out that trust and opportunism seem to be 'less important.... than one might have assumed'. However, they do acknowledge that qualitative research, which is more likely to reveal social phenomena such as interpersonal trust, is 'under-represented in the field'.

In the same special issue of *Organization Studies* Sobrero and Schrader (1998) surveyed forty journals in an attempt to develop a 'metatheory' of inter-firm relationships. Despite many network studies which vary from industrial districts (Piore and Sabel, 1984) to detailed microsociological approaches (Granovetter, 1985; Steward and Conway, 1996) there has been little attention devoted to analysing 'the detailed structuring of those relationships' (Sobrero and Schrader, 1998). In an attempt to resolve this problem the authors suggest that there are two dimensions which are 'fundamental' to the management of inter-firm relationships: contractual and procedural coordination. Contractual coordination refers to the legally defined exchange of rights (Stinchcombe, 1990; Williamson, 1985) while procedural coordination refers to the structural mechanisms which are necessary for the exchange of information and organisational learning (Burns and Stalker, 1961; Duncan, 1976; Levitt and March, 1988; Nonaka and Takeuchi, 1995). The separation of organisational responsibility means that senior managers and lawyers will be

responsible for contractual coordination and business unit managers and functional managers (R&D) will be responsible for procedural coordination.

Sobrero and Schrader (1998:590) quote Doz *et al* (1989:136) who state that actual coordination is achieved not through contractual means but by patterns of communication involving individual employees: 'Top management puts together strategic alliances and sets the legal parameters for exchange. But what actually gets traded is determined by day-to-day interactions of engineers, marketers, and product developers'. In other words, there is emphasis on the processual elements which underpin the exchange of information and knowledge. Coordinating activities are related to the distinction between uncertainties about the means needed to attain a particular goal and uncertainties about the goal itself (Thompson, 1967). The level of uncertainty combined with issues of 'asset specificity' has direct implications for the structuring of relationships between cooperating organisations.

In attempting to link the various perspectives, Sobrero and Schrader (1998) develop a model which has two dimensions: task characteristics (level of uncertainty) and structuring dimensions (contractual and procedural coordinating mechanisms). The authors then set out to test a number of hypotheses generated by their model: for example, 'Do task characteristics influence the level of contractual coordination and procedural coordination?' (Sobrero and Schrader, 1998:595). A survey of forty journals revealed 118 'networking' articles which were reduced to 32 studies which combined an explicit theoretical framework and empirical data. The meta-analysis confirmed links between task characteristics and contractual coordination but evidence related to the role of procedural coordination was 'ambiguous'. By way of explanation the authors point to problems with operationalising certain constructs in some studies as well as greater emphasis on contractual coordination. However, evidence from the paper does have implications for inter-organisational research: first, the unit of analysis should be a single relationship, secondly a range of relationships should be examined (not only joint ventures and strategic alliances). Thirdly, the 'relational perspective' is a 'promising and rather under-explored area of development in inter-organizational research' (Sobrero and Schrader, 1998:609). That is, there is a need for work in the social network tradition to be applied to the study of links between firms.

Actors and Innovation Networks

Hakansson's (1987) book which examined industrial technological development signified a growing interest in the study of networks. Recently, a number of other edited books reflect the importance of networks both as a new organisational form and a way in which management complement their internal competences (Nohria and Eccles, 1992; Coombs *et al*, 1996; Ebers, 1997; Child and Faulkner, 1998). For two main reasons we have not reviewed these books as a whole nor individual contributions. First, other than Coombs *et al* (1996) the focus is more general than our own concern with 'innovation networks'. Secondly, in the UK at least, Research Assessment Exercise (RAE) pressures mean that significant contributions to the literature will almost certainly be published in journals. In other words, chapters which appear in edited books are likely to be variations on themes published elsewhere.

In this paper we examine significant contributions to the study of innovation networks published in a range of journals over the last thirty years.Unlike the two articles in the 'inter-firm' special issue of *Organization Studies* (Oliver and Ebers, 1998; Sobrero and Schrader, 1998) we do not utilise statistical techniques as a means of analysing the 49 contributions we have identified. Rather, we adopt a broadly interpretive approach in attempting to set out the key themes and theories which inform work on the topic of innovation networks. Our focus is more specific than general inter-firm relations and we concentrate our survey on ten journals in which the emphasis is technological innovation. We acknowledge that there are a small number of important papers which were published in other social science journals and we mention the seminal contributions made by Granovetter (1973; 1985) as well as significant papers by Perry (1993) and Powell *et al*, (1996).

In recent years writers from a number of disciplinary areas have adopted or utilised the term innovation network. Contributors to actor network theory, regional networks, policy networks and supply chain linkages have enriched our own understanding of innovation networks and some representatives of these areas are included in this review. However, our judgement is that the objectives, interests and key research questions of those contributing to these perspectives are very different than our own (see below). Law (1999:2) refers to the 'multi-national monster' of the actor-network approach now that it has been converted

into 'smooth and consistent theory'. Law himself, along with Callon (1986) and Latour (1988) were key figures in the development of the actor-network theory in which technical creation (innovation) stems from numerous interactions of researchers, scientists, technologists, engineers, managers, customers and users. Techno-economic-networks (TENs) are defined as: 'a coordinated set of heterogenous actors' which included public laboratories, research centres, companies, financial institutions, government, and users' (Callon, 1992:73). TENs may be stable, producing technologies that are relatively easy to characterise, or dynamic (having significant degrees of freedom), developing unexpected technologies. Such networks are organised around three 'poles': the scientific pole which produces empirical knowledge (universities and research centres); the technical pole which develops artifacts from the empirical knowledge leading to models, pilot projects, prototypes; finally, the market pole which incorporates users who have a need which is either overt or latent.

Callon (1992) brings together the economic and the social with his concept of intermediaries which link various poles in the network: *text* (reports, journals and software), *technical objects* (telephones, fax machines, computers, vehicles), *skills* (ability to mobilise a social network as well as technical skill required to use a computer) and finally *money* (research grants, profits, budgets, sales income and other revenues). The term 'sociology of translation' is used by Callon to describe the development and stabilisation of technology while reconciling the distinction between the social and the technical. In his view, networks comprise links between various 'actants' (human and non-human) which he describes as 'heterogenous entities'. Networks are configured by 'enrolling' actants through a process of negotiation which has four stages. First, *problematization* occurs when one or more actors attempt to define a problem and set the parameters for potential solutions. Secondly, *interessment* is the stage at which the 'enrollers' attempt to persuade others that theirs is the best solution. Thirdly, actors (human and non-human) are *enrolled* into the new network by coercion, seduction or consent. The final stage, *mobilisation*, occurs when rules are established to sustain the network which may represent a larger constituency (see Grint and Woolgar, 1998).

A more pragmatic group of scholars are those characterised by Clark and Staunton (1993) as the 'Stockholm School' who utilise network concepts such as actors, resources and activities to revise neo-classical economic theory. Studies of Swedish innovation networks by those such as Hakansson (1987) suggest that different time frames make synchronisation

difficult and the heterogeneous nature of organisations means that 'learning' is subject to high levels of trial and error (Clark and Staunton, 1993: 167). Hakasson (1987) himself is critical of work in which product development (innovation) is seen as being initiated by producers, users or some 'interplay' between the two. His view is that product development is the outcome of many small and independent events:'The network is a social construction and as such built upon social relationships between actors' (Hakansson, 1987:493). Such a perspective is complementary to our own approach but Hakansson and his colleagues focus on supply chain relationships which are common in industrial markets. For example, he concludes that an organisation's ability to network is defined by a combination of resources and activities. Similar work has been carried out by those associated with the concept of 'lean manufacturing'. Lamming (1993:245) suggests that the switch from traditional adversarial relationships between customer and supplier in the auto-industry emphasise the 'importance of joint development of new technologies, using complementary assets in the process'.

Much of the literature associated with regional networks has used the development of high-technology sectors in California as a key reference point. Although Saxenian's (1991:424) contribution to the Montreal Conference (special issue of *Research Policy*) was ostensibly about production networks she states: 'Silicon Valley demonstrates how inter-firm networks spread the costs and risks of developing new technologies and foster reciprocal innovation amongst specialist firms'. More recently, Koschatzky (1998:385) notes that studies carried out in the US using patent data or the Small Business Administration census 'reveal proximity effects in the innovation activities of industrial firms, universities and business services'. The identification of high-tech regions has implications for policy-making as national governments have tried to replicate the successes of Silicon Valley, Emilia-Romana and Baden-Wurttemberg. Porter (1998:xxiii) has been particularly influential suggesting there is 'mutual dependence' between government and business because 'many of a company's competitive advantages lie outside the firm and are rooted in locations and industry clusters'. In recent years the study of policy networks has emerged as an important theme in literature related to the social risks associated with innovation. Key writers such as Brandes *et al* (1999) have adopted an approach which is similar to social network analysis (see below) for identifying relational configurations in the formation of policy networks.

Structure, Embeddedness and Innovation Networks

Social network analysis (SNA), incorporating work on scientific, R&D and entrepreneurial networks, provides tools and techniques for the collection, analysis and presentation of relational data. The approach reveals structural properties including size (number of actors) and density (number of linkages) as well as identifying cliques, key actors and isolates. SNA has largely been applied to networks of individual actors but this does not preclude the study of organisational linkages. For example Hagedoorn and Schakenraad (1992) employ multi-dimensional scaling (MDS) techniques to reveal cliques and clusters amongst networks of organisations in a range of IT-based sectors (also see Hagedoorn and Schakenraad, 1991) .

Early work on the social organisation of science focused on defining the principal norms governing scientific activity (see Barber 1952). Emphasis then shifted towards communication patterns of scientists and the associated social structure of scientific networks (Price, 1963; Price and Beaver, 1966; Garvey *et al*,1970; Lin *et al,* 1970). By the early 1970s researchers were linking the growth of scientific knowledge (Kuhn, 1962) with the social organisation of scientists (Crane,1972; Griffith and Mullins, 1972). Studies concerning the communication patterns of scientists have repeatedly demonstrated the crucial role of informal personal networks in scientific information systems (Herner, 1954; Menzel, 1962; Wolek and Griffith 1974). Research also revealed two important subgroups: *solidarity groups* (Crane 1972) which form around highly productive scientists and *invisible colleges* (Price and Beaver, 1966; Crane, 1972) which represent elites of highly productive scientists engaged in the informal transmission of information.

The social organisation and communication patterns of engineers and technologists also became a significant area of research interest in the early 1970s (Allen, 1970; 1977; Frost and Whitley, 1971). While emergent informal communication networks were recognised as being important in engineering-based R&D it was argued that:

> **'...communication patterns in the two areas of activity [science and technology] are not only largely independent of one another, but qualitatively different in their nature' (Marquis and Allen, 1966: 1052).**

Variations in the social organisation of scientists and engineers can in part be explained by different sets of norms and values. Allen (1977: 40) argues that unlike scientists, engineers 'are limited in forming invisible colleges by the imposition of organizational barriers'. This 'enforced localism' means that engineers only work on problems that are of interest to their employer and must refrain from early disclosure of research results: 'both of these

constraints violate the rather strong scientific norms that underlie and form the basis of the invisible college' (Allen, 1977:41). Nevertheless, Larson and Rogers (1984:79) do stress the importance of friendship, job mobility, social foci and spatial proximity to the 'free-wheeling information exchange' between engineers in competing micro-electronics companies in Silicon Valley.

Johannisson and Peterson (1984:1) note the apparent paradox that, on one hand, entrepreneurship 'personifies individualism and independence' while on the other hand individuals are 'very dependent on ties of trust and cooperation'. Competent entrepreneurs draw on personal networks to extend strategic competences and help resolve acute operating problems by supplementing internal resources (Birley *et al*, 1991; Conway, 1997; Conway and Shaw, 1999). Leonard-Barton (1984:113) suggests that 'entrepreneurs who, for geographic, cultural or social reasons, lack access to *free* information through personal networks, operate with less capital than do their well-connected peers'. Equally, it is recognised that effective personal networks 'must become as complex and as heterogeneous as the daily activities of the venture' (Johannisson and Peterson, 1984:4). Inherent in the maintenance of such networks is the need for entrepreneurs to continually create *weak-ties* to prevent a few strong-ties from closing their network to opportunities and alternatives (Leonard-Barton 1984; Aldrich and Zimmer 1986). A recent comparative study of entrepreneurship established the importance of managerial education in encouraging the creation of networks. A lack of experience in higher education means that entrepreneurs have neither the personal contacts which are a source of information nor any real understanding of the expertise available through links with universities (Jones *et al*, 1997). Much of this work is based on Granovetter's (1973) concept of weak ties which are an important potential source of knowledge and information (see Fletcher, 1998; Shaw, 1998). Strong ties constrain access to innovatory ideas and knowledge sources whereas weak ties open up networks which provide access to new areas of expertise. At the same time, entrepreneurial activity is embedded in complex networks of social relations which are based on family, state, educational and professional background, religion, gender and ethnicity (Granovetter, 1985).

Social Interaction and Innovation Networks

Those writing about networks generally adopt a functionalist perspective which is based on a biological metaphor which emphasises that the structure and functioning of social systems is evolutionary and adaptive (Morgan, 1986). Network scholars can be broadly divided into those who favour structural explanations (Allen, 1970; Hakansson, 1987; Powell *et al*, 1996) in which the social system as a whole (the network) is pre-eminent over individuals and, secondly, those whose consider human action (Leonard-Barton, 1984; Conway, 1994; Shaw, 1998) to be the key explanatory factor in the formation of networks. All social

structures (networks) encompass the enduring pattern of social interrelations such as class as well as roles, rules and social institutions. Therefore, it is necessary to resolve the endemic agency-structure dualism by emphasising the way in which knowledgeable, reflexive social actors draw on rules and resources in their day-to-day social activity (Giddens,1984). This recursive activity constantly recreates the 'structural properties' that provides the framework for everyday social practices (Jones, 1997a; Jones *et al*, 2000). Giddens (1984) uses the terms system and structuration to emphasise that the rules and resources drawn on in the (re)production of social action are at the same time the means of system reproduction. Social systems do not have structures but exhibit structural properties. In structuration theory the relationship between agency and structure is similar to the association between grammar and speech. The rules of grammar are utilised by social actors in their patterns of communication which in turn constantly recreate the structure of language.

Structuration theory and networks are brought together in Barley's (1990) analysis of new technology and the revised structural arrangements in two hospitals. Using the concepts of relational and non-relational roles he 'explicitly articulates how skills, tasks, and activities influence role relations and how role relations, in turn, affect an organization's and an occupation's structure' (Barley, 1990:98). In a recent paper, Barley and Tolbert (1997) develop a more dynamic model in which they categorise day-to-day interactions by identifying the 'scripts' used by actors. Scripts are the 'observable, recurrent activities and patterns of interaction characteristic of a particular setting' (Barley and Tolbert, 1997:98). This means that networks cannot be studied as objective social structures which are independent of human agency. As Roberts and Grabowski (1996:418) point out: 'organisational researchers are now more explicit in acknowledging that social activity is embedded in social networks which include family, friends and co-workers as well as broader factors such as religion, gender and ethnicity'. In contrast, Latour (1999:15) argues that after twenty years the term 'network' has lost its freshness 'as a critical tool against notions as diverse as institutions, society, nation-state and, more generally, any flat surfaces'. He also objects to those who use actor-network in the same sense as agency-structure: 'Most of the misunderstandings about ANT have come from this coupling of terms...'. Rather, Latour sees actor-network theory as a way of paying attention to 'dissatisfactions' associated with attempts to understand society from either the micro or macro levels. Micro level (face-to-face interaction) dissatisfactions are related to the problem 'that many of the elements necessary to make sense of the situation are already in

place: norms values, culture, structure, social context'. Macro level dissatisfactions concern abstractions of terms such as structure and culture which seem too great and there is a need to reconnect to 'flesh and blood local situations from which they had started' (Latour, 1999:17).

Our interest in the topic of networks is concentrated on the way in which business organisations manage the innovation process. In other words, we are concerned with examining various stages from idea generation to the implementation of new products, services and processes. Innovation networks may involve the analysis of social interaction within organisations or the focus may be external linkages such as joint ventures and strategic alliances. In either case, the research interest could be formal linkages defined by organisational structures and contractual agreements or on the informal linkages associated with the 'grapevine' and what have been described as 'invisible colleges' (Crane, 1969). Both formal and informal linkages contribute to innovatory performance by providing access to new skills, knowledge, information and technologies. This does not mean that we adopt a managerialist approach in which networking is simply seen as a way of improving the effectiveness with which knowledge is acquired and utilised. Rather, we are attempting to better understand the process by which new products and services are created because as Schumpeter (1943) points out innovation is 'the fundamental engine that sets and keeps the capitalist engine in motion'. Therefore, it is important to question decisions about technology at organisational (Jones, 1997b) and societal levels (Steward, 1995).

In his review of the literature Freeman (1991) discusses definitions of the term 'innovation network'. These range from the view that they are 'basic institutional arrangements to cope with systemic innovation' (Imai and Baba, 1989) to those linkages which are 'of a mainly informal and tacit nature' (Camagni, 1991). Our definition emphasises the idea of networks as a way of understanding organisational innovation:

> **An innovation network is a conceptualisation of the innovation process as a complex and pluralistic pattern of interactions, exchanges and relationships between actors participating in that process.**

Hence, innovation networks incorporate the formal and informal linkages which are established within and across organisational boundaries as a means of capturing codified knowledge represented in specifications, reports and software as well as tacit knowledge which can only be communicated by direct social interaction (Nonaka and Takeuchi,1995). Networks are formed or emerge in response to some perceived need within organisations for

knowledge which will contribute towards the development of new products, processes or services. The formation of any innovation network is a process by which random patterns of social activity which are gradually institutionalised into organisational routines (Nelson and Winter, 1982).

From a methodological perspective we concur with Giddens (1984:284) who argues that 'all social research has a necessarily cultural, ethnographic or "anthropological" element to it'. This relates to what he describes as the double hermeneutic in which there is intersection between the two frames of reference represented by the world as understood by lay actors and the 'metalanguages' utilised by social scientists. That is, competent actors develop their own understanding of social life which is interpreted by social scientists making use of 'second order concepts'. Researchers must be sensitive to the complex skills utilised by actors in coordinating their everyday behaviours and practices. Structuration theory also encourages researchers to take into account the time-space constitution of social life which has traditionally been left to historians and geographers. History and context are central to studies which are intended to reveal the process of technological innovation. At the same time, Giddens (1984) rejects the search for universal laws found in natural science because they simply do not exist in the 'realm of human social conduct' .

While we have set out our own perspective on the links between social interaction and innovation we accept that there is no single theory of networks. In fact, we broadly concur with Martin and Frost (1996:610) who in discussing postmodernism make the following point: 'it is a discourse, rather than a unified theory'. At the same time, we reject an extreme relativistic perspective in which 'anything goes'. Though repudiating the idea of a metatheory of innovation networks we still believe that it is important to retain an historical perspective on organisational change. For example, the idea of the 'virtual' or networked firm is not a feature of postmodern society - such firms were typical of industrial organisation well into the C20th (Pollard, 1965). Collaborative agreements are seen by those from an economic perspective as a way of decreasing uncertainty and the likelihood of cheating. But attempts to reduce the complexity of human behaviour to mutual expectations about future behaviours are clearly inadequate. Sociological approaches to inter-organisational relations are important because *trust* is conceptualised as 'a communicative, sense-making process' (Clegg and Hardy, 1996:679).There is also a need for a more critical analysis because collaboration is often seen as an activity from which partners benefit equally. Although many collaborative deals no doubt are beneficial to all parties it is also important to recognise that such arrangements can also be exploitative: 'existing work has been noticeably mute on questions relating to power' (Clegg and Hardy, 1996:679).

Researching Innovation Networks

Those studying innovation networks have utilised a wide range of methodologies and have adopted an eclectic array of theoretical positions. Some researchers such as Powell *et al* (1996) adopt a positivistic approach to the study of networks based on statistical analyses of data acquired from a relatively large (225 firms) data set. In contrast, others such as Knights *et al* (1993) adopt a post-structuralist perspective based on *data* from a single case study. In this section we briefly summarise the contrasting approaches utilised in some of the more significant network studies undertaken in recent years.

In the past firms organised the major elements of their R&D internally and contract research was primarily concentrated on relatively mundane activities such as toxicological tests. According to Powell *et al* (1996) companies are increasingly performing all stages of the innovation process (discovery to marketing) through some form of networking arrangement. There are many explanations for this increase in networking including shared risk, market access, complementary assets and speed to market. Powell *et al* (1996) focus on the argument that networking is more prevalent in sectors (biotechnology for example) where knowledge is developing rapidly and sources of innovation are likely to be found in the 'interstices between firms' which includes universities, suppliers and customers. It is claimed that the level of technological sophistication will be 'positively correlated with the intensity and number of alliances in those sectors' (Powell *et al*, 1996:116). The study is theoretically underpinned by a view of innovation and organisational learning as a function of the firm's access to knowledge (March, 1991; Nelson, 1990; Stinchcombe, 1990) and its 'absorptive capacity' (Cohen and Levinthal, 1990). The methodology utilised a database, assembled by the authors, of independent dedicated biotechnology firms (DBFs) and their formal contractual, inter-organizational agreements. Data were collected over a five year period from 1990 to 1994. The authors were able to examine a range of factors associated with networking activity including heterogeneity, central connectivity, degree centrality and closeness centrality (Powell *et al*, 1996:127/8). It was also possible to create a 'dynamic model' by tracking changes to network relationships over the five-year period. A number of important issues emerged from the study of 225 biotechnology firms, in particular, the lack of influence of traditional organisational variables such as age and firm size: the former proved 'unimportant in the context of network experience, and size was an outcome rather than a determinant of partnerships' (Powell *et al*, 1996:142). A 'path-dependency' cycle of learning was also identified with early exploration leading to positive

feedback which reinforced the importance of R&D alliances as the 'locus of innovation'. In addition, the 'modal' firm was typified by multiple relationships and those without ties were extremely rare.

In their article, Knights *et al* (1993) begin by pointing out that most studies of inter-organisational networks lack any 'critical' dimension. The data are based on a study of 'Switchco' which, in 1990, was established to facilitate electronic trading between 20 insurance companies. The authors focus on those 'knowledge workers' who were responsible for establishing and developing the electronic trading network. A conceptual framework was developed by combining actor network theory (Callon, 1986) and Foucault's (1986) theory of power and knowledge. Most studies emphasise 'reciprocity and mutual trust, where self-interest is sacrificed for the common good' while ignoring evidence which suggests that networks are 'embedded in institutional power relations that are hierarchical, competitive and instrumental' (Knights *et al*, 1993:979). Actor network theory helps reveal the political activities within Switchco which made it difficult to establish a clear corporate view on the electronic trading network. Foucault's work is utilised as a way of moving beyond 'middle-range' theories which ignore 'wider structures of inequality'. Hence, strategic inter-organisational networks can be seen as a 'disciplinary technology' by which 'capitalist economies revolutionize their means of production' (Knights *et al*, 1993:988). In other words, networking fits with what du Gay (1996) describes as 'new wave management' in which employees are encouraged to believe that they are acting as independent 'enterprising subjects' when, in fact, they are closely monitored and controlled by senior managers.

A study by Conway (1995) of 35 'commercially successful innovations' moves beyond the single case study while retaining the deeper analysis associated with qualitative research. The study, designed to investigate the role of informal boundary spanners, was informed by 'social exchange theory' (Uehara, 1990) which emphasises the reciprocity obligations which are a feature of social interaction. The concept of 'action sets' was used to describe the range of dyadic relationships associated with some specific social activity such as the innovation of a new product. Conway's (1995) sample was drawn from the winners of two prestigious UK innovation awards: The Queen's Award for Technological Achievement and the British Design Awards. Interviews were carried out with 'focal actors' associated with the 35 award winners to identify a range of relationships mobilised in the innovation process: 'the nature of the dyadic link (exchange of friendship, power, information or

goods); the degree of formalisation; the degree of reciprocity or symmetry; the extent of multiplicity (single or multiple links); the strength or intensity of the relationship' (Conway, 1995: 330). While the results indicated that economic outcomes were a feature of boundary spanning activity there was also support for the proposition that informal exchange behaviour is highly complex. In many cases information was exchanged or resources obtained because of friendship ties with no expectation of financial return.

> **David who had come to work for me, used to work for CEGB, and he knew somebody called Greg. And Greg has gone up in CEGB. He phoned Greg and said "Look we need to borrow a piece of equipment." And Greg said "Right OK" (Conway, 1995: 337).**

In conclusion, Conway argues that it is essential for policy makers and those involved with the management of innovation to acknowledge the importance of informal friendship ties if technological change is to be managed effectively. We do not claim that these three papers are entirely representative of empirical studies of innovation networks. Our point is that the work of Powell *et al* (1996), Knights *et al* (1993) and Conway (1995) illustrate the range of theoretical and methodological approaches to the study of collaborative links during the innovation process. In the following section we analyse 49 papers which we have identified as making a significant contribution to the literature on innovation networks.

Issues of Theory and Method

In appendix 1 we summarise the contributions of 49 papers based on four factors: theory, method, analysis and sample. That is, we have attempted to identify the theory which underpins each paper as well as the methodological approach, the nature of the analysis and the sample on which the studies were based. In a substantial number of papers issues of theory, method, analysis and sample are what might be described as 'opaque'. This is particularly evident with regards to defining 'theory' which is often implicit rather than explicit (see Hagedoorn and Schakenraad, 1992; Rothwell and Dodgson, 1991; Lawton Smith *et al*, 1991). The largest proportion of papers adopt a 'network' perspective which is described by Oliver and Ebers (1999:575) as focusing on how the position of actors in a network and the content of relations affect opportunities for action (Burt, 1992; Powell, 1990). Some authors combine network theory with another theory such as 'organisational learning'(Senker and Sharp, 1997; Tidd, 1993). If the rigorously defined theoretical approaches such as social exchange theory, social embeddedness, actor network theory and social network theory are grouped under the generic title of networks then they account for

more than 50 % of the contributions.

The main methods of data collection were interviews, questionnaires and secondary data sources. Many authors lack precision in explaining their research approach in terms of number and length of interviews and whether respondents were interviewed on more than one occasion (Graham, 1998; Senker and Sharp, 1997). Similar issues are also apparent when examining research based on questionnaire data (Midgley *et al*, 1992; Rothwell and Dodgson 1991). Such problems are exacerbated when studies are based on secondary sources as authors appear unwilling, or perhaps regard it as unimportant, to specify the exact nature of their data and the way in which they were acquired (Gemser *et al*, 1996; Robertson and Langlois, 1995).

Approaches to data analysis, as well as research methodologies, can be categorised as qualitative or quantitative. In general, those adopting quantitative approaches utilise some form of statistical analysis ranging from cluster analysis and multiple dimensional scaling to simple descriptive statistics. It would be fair to say that overall there is a lack of sophistication in the usage of statistical techniques amongst the majority of papers represented here. Qualitative approaches are both more varied and in some cases considerably more sophisticated in the nature of the analysis. Steward and Conway (1998) utilise discourse analysis to identify different approaches to green innovation in German and UK small firms. Macro and micro levels are combined by von Raesfeld Meijer (1998) who draws on socio-cognitive mapping to analyse a complex case study involving a project to rebuild Den Bosch bus and rail stations in Amsterdam. Most of those utilising qualitative methodologies adopt what might be described as a 'discursive' approach to their data analysis (reaching a conclusion *via* reasoned argument). Generally, this means using a particular theoretical framework to order and categorise data obtained from interviews or secondary sources. Perhaps the best example is the contribution by Knights *et al* (1993) who combine actor network theory and Foucault's concept of power-knowledge to critically analyse an attempt by UK insurance companies to establish an electronic trading system (see above). Another notable piece of work utilising this approach is Perry's (1993) historical analysis of the Manhattan Project.

Of the papers which we surveyed only seven were based on relatively large samples; Autio (1997) studied 130 firms; Baptista and Swann (1998) used the SPRU database to analyse 284 manufacturing firms; Hagedoorn and Schakenraad (1992) examined 1700 'alliances' between 210 firms; Hakansson (1990) made between 1 and 6 interviews in 123 firms;

Karlsson and Olssson (1998) surveyed 279 Swedish firms; Powell *et al* (1996) made a longitudinal study of 225 biotechnology companies; Swan and Newell (1995) carried out 20 interviews and obtained a questionnaire sample of 189. Rothwell and Dodgson (1991) did include a sample of 100 UK and 80 Italian SMEs but there is a lack of clarity about when and how data on these firms were acquired. There are a number of mid-range studies which have samples greater than 10 but less than 100 (Conway, 1995; Kreiner and Shultz, 1993; Lawton Smith *et al*, 1991; Midgley *et al*, 1992; Steward and Conway, 1998). We do not suggest that large samples equate with quality nor that the findings from very small samples are trivial. The cases studied by Graham (1998), Knights *et al* (1993), Perry (1993) and von Raesfeld Meijer (1998) all tackle complex and significant topics. We can summarise the strengths and weaknesses of the network literature in the following manner. There are a number of important papers which have implications far beyond the relatively narrow field of innovation studies. In particular, the work of Knights *et al* (1993) and Powell *et al* (1996) which was summarised above. We do not regard the diversity in theory, method, analysis and sample size as a weakness but we do feel that all authors should be encouraged to clearly set out these key elements of their research approach.

Conclusion: What is to be Done?

Fombrun (1982,280-281) contends that 'network analysis is a powerful means of describing and analysing sets of units by focusing explicitly on their inter-relationships' which are 'seen as *embedded* in a context that both constrains and liberates'. While DeBresson and Amesse (1991:363) argue that 'the network approach has something original, useful, and durable to bring to innovation studies'. Networks can be visualised as sets of links which represent the relationships between various actors involved in the innovation process. Information, knowledge, goods, power and friendship are exchanged between actors and *flow* through the network along individual dyadic links (Tichy *et al*, 1979). Although in principle networks are *unbounded* most researchers find it necessary to set limits for analytical purposes. Early advocates of the approach approach included Rogers and Kincaid (1981:127) who observed that 'the shift from the predominant use of individuals as units of analysis, toward network analysis, usually begins with dyads as units of analysis'. However, many writers (DeBresson & Amesse, 1991; Auster, 1990) stress that networks are greater than the sum of their interacting parts and should not be viewed simply as *portfolios* of dyadic links.

Despite widespread recognition that personal networks are crucial for technological interchange, Freeman (1991:502) contends that they have received very little attention from researchers: 'informal networks are extremely important, but very hard to classify and measure'. To unravel the complex processes which underpin successful technological innovation it is essential to systematically explore the complex patterns of personal interaction within and across the boundaries of development teams, innovative organisations, industrial sectors, and geographical regions. A considerable amount of research indicates that innovation does not occur as a result of one single event but emerges from a *bundle* or *ensemble* of ideas, information, technology, codified knowledge and know-how which may or may not be embodied within the product or process (Myers and Marquis 1969; Utterback 1971; Allen 1977; Conway 1994). Nor, in general, do new ideas appear fully formed and articulated from a single source (Allen *et al*, 1983). Thus, the strength of the network approach is that, on the one hand, it allows a detailed analysis of the dyadic links mobilised in the innovation process while, on the other, it provides a framework for exploring the multiple sources and pluralistic patterns of communication typical in the development of technological innovation (Steward and Conway 1996).

A number of research projects have been undertaken at Aston Business School to redress the imbalance between the metaphorical approach (Collins, 1974) and the mathematical orientation (Brieger, 1976) by examining the role, nature and importance of informal links in the development of successful technological innovations (Steward & Conway, 1996; Conway, 1994, 1995). In contrast to much of the innovation network research undertaken in recent years, our focus has been concerned as much with notions of 'network as method' as with 'network as a phenomenon'. As a consequence, work has focused on developing creative ways of researching and mapping innovation networks. Steward *et al* (1994) argue that since about half the brain is dedicated to visual processing, a graphic-based system is the most natural way for people to understand and manipulate relational data. While Conway and Overton (1994) identify the value of the network graphic, over textual and matrix displays, for its ability to encode a variety of quantitative and qualitative data in an efficient and effective manner.

Following our review of the innovation network literature we believe that the following issues need serious consideration by those working in the area. First, as Salancik (1995) suggests what is needed is a good (innovation) network theory of organisation. Far to many studies rely on what might be described as crude empiricism. Secondly, much of the work is

based on questionnaire data or interviews which provide very little context for understanding the dynamics of innovation networks. We accept that there are numerous problems associated with ethnographic research but at the same time we believe that there should be far more emphasis on detailed qualitative approaches to the collection of data. As Freeman (1991:511) argues, longitudinal case studies would enable us to gain a much fuller understanding of the complexity associated with innovation networks. Finally, we suggest that there is a need to deal with what Latour (1999) describes as the micro-macro level 'dissatisfactions'. Although Latour rejects actor-network theory as a means of resolving the agency-structure dichotomy we believe that such considerations are central to understanding networks as subjective structures which cannot be separated from their social context. In other words, networks do not have the kind of objective reality that is apparently assumed by many of the authors reviewed here.

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Appendix 1: CONTRIBUTIONS TO INNOVATION NETWORKS

AUTHOR(S)	THEORY	METHOD	ANALYSIS	SAMPLE
Allen (1971)	Networks & gatekeepers	Questionnaire	Statistical & mapping	R&D laboratory
Autio (1997)	Resource-based	Comparison of three databases	Statistical (t-tests)	82 (US); 29 (Fin); 19 (UK)
Baptista & Swann (1998)	New growth externalities (networks)	SPRU database; employment data (CSO)	Statistics (OLS & linear exponential modelling)	284 manufacturing firms (1975-82)
Belussi & Arcangeli (1998)	Evolutionary	Secondary sources	Discursive/ comparative	Case studies of 3 Italian regions
Chesbrough & Teece (1996)	Innovation type (systemic/autonomous)	Secondary sources	Discursive	Case Study: IBM & the PC
Conway (1995)	Social exchange	Semi-structured interviews	Identifying exchange value	35 award winning firms
Conway & Steward (1998)	Social exchange	Semi-structured interviews	Graphical network maps (software)	Three SME cases
Cooke (1996)	Networks	Secondary sources	Cross-national comparisons	Seven regions and/or countries
Cooke & Morgan (1994)	Public policy	Interviews and secondary sources	Basic statistics; structured analysis	80 respondents (gov, TU, ind)
Czpiel (1975)	Sociological diffusion	Interviews: technicians & managers	Sociometric mapping	18 continuous casting firms
DeBresson & Amesse (1991)	Networks	Literature review		
de Laat (1999)	Innovation type (systemic/autonomous)	Secondary sources (trade journals)	Discursive	Case study: digital video disk (DVD)
Fletcher (1998)	Social embeddedness	Ethnographic	Attributing values & meaning	SME (70 employees)
Foray (1991)	Transaction costs	Secondary sources	Comparative	Two case studies
Freeman (1991)	Networks	Literature review		
Frost & Whitley (1971)	Networks & gatekeepers	Two separate questionnaires	Statistics (Mann-Whitney)	R&D laboratory
Gemser *et al* (1996)	Life-cycle & appropriability	Secondary sources	Comparative	Three industry case studies
Graham (1998)	Actor network theory	Extensive interviews	Discursive	UK electronic livestock auctions
Hagedoorn & Schakenraad (1992)	Networks	CATI databank	Cluster analysis; multi-dimensional scaling	210 firms - 1700 alliances
Hakansson (1990)	Networks	Structured interviews - 27 items	Descriptive statistics	123 firms (1 to 6 interviews)
Hislop *et al* (1997)	Articulation process	Literature review		
Hobday (1994)	Complementary assets & PLC	Secondary data	Discursive	Silicon Valley in 1980s
Jones *et al* (1998)	Structuration theory	Literature review		
Karlsson & Olsson (1998)	Network externalities	Postal survey (questionnaire)	Statistical (tobit) comparative	140 large firms; 130 SMEs

Knights *et al* (1993)	Actor network theory + Foucault	Qualitative (not stated)	Discursive	Switchco
Koschatzky (1998)	Spillovers and networks	Survey - questionnaire	Logistic regression	2042 SMEs in 4 regions
Koski (1999)	Network externalities	Questionnaire - input-output data	Statistics (OLS & descriptive)	Finnish firms: 15 (1994); & 6 (1996)
Kreiner & Shultz (1993)	Barter economy	16 in-depth interviews	Discursive	Biotechnology research directors
Laamanen & Autio (1996)	Life-cycle & dyn. complementarities	Secondary data	Discursive	Finnish electronics industry
Langlois & Robertson (1992)	Networks	Secondary sources	Comparative	Case studies: hi-fi stereo & P.C.s
Lawton Smith *et al* (1991)	Networks	Interviews	Compare large & small firms	27 firms (international)
Midgley *et al* (1992)	Structural equivalence	Questionnaire	Network mapping	16 Australian firms
Perry (1993)	Institutionalist	Secondary sources	Retrospective mapping	Case study: Manhattan project
Powell *et al* (1996)	Networks & learning	Analysis of formal agreements	Multiple regres-sion & correlation	225 firms (largely US)
Robertson & Langlois (1995)	Networks	Secondary sources	Discursive	None
Robertson *et al* (1996)	Innovation diffusion	Semi-structured interviews + documents	Structured comparisons	3 large firms
Rothwell (1992)	Interactive innovation	Literature review		
Rothwell & Dodgson (1991)	Networks	Questionnaire	Basic statistics (numbers)	100 UK& 80 Italian SMEs
Senker & Sharp (1997)	Networks & organisation learning	Interviews; 35 + 14 (??)	Comparative	7 paired cases: MNC/DBF (Europe/US)
Shaw (1998)	Social network theory	Un/semi-structured + participant obs	Mapping + bartering exchange	5 small graphic design firms
Steward & Conway (1998)	Social Networks	Interviews (SS) + documents	Discourse analysis	20 cases - UK & Germany
Swan & Newell (1995)	Innovation diffusion	Semi-structured Interviews & questionnaire	Multiple regres-sion., correlation, descriptive stats	20 interviews + 189 questionnaires
Tidd (1997)	Networks and learning	Literature review		
Tidd (1993)	Technological fusion	Secondary sources (?)	Discursive	7 UK-based MNCs
Teubal *et al* (1991)	Evolutionary	Secondary sources	Comparative	None
Turpin *et al* (1996)	Networks & bricoleurs	Secondary sources (not stated)	Structured comparisons	4 paired cases Australia & China
Von Raesfeld Meijer (1998)	Social cognition	Interviews, , obser-vation, documents	Socio-cognitive mapping	Case: Den Bosch bus/rail station
Yli-Renko & Autio (1998)	Systemic evolution (embeddedness)	Interviews, firm & secondary data	Discursive - comparative	5 high-tech firms
Zander (1999)	Networks (international)	Patent data [US + Sweden] (1946-90)	Cluster analysis	24 Swedish MNCs