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« Networks and Innovation : A Survey of Empirical Literature »

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Networks and Innovation:

A Survey of Empirical Literature

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Abstract

Networks are now understood to be an important mechanism to change economic and social outcomes through non-market means, and one of these outcomes is the contribution of networks to innovation and technological change in general. This survey covers the recent literature on networks as far as they have implications for knowledge transfer among actors, innovation and technological change. We present a recent survey of empirical research, covering inter-firm and intra-firm networks, since these are accepted to have the most important impact on knowledge dissemination and innovation. One important conclusion that can be derived from the survey is that, although there exists a tremendous increase in network research, it is still difficult in most cases to draw robust conclusions and generalizable results. Therefore, one of the aims of this survey is to highlight those areas in which some consensus has been achieved in the literature, and others which need more attention and research in the future.

1. INTRODUCTION

Networks are now understood to be an important mechanism to change economic and social outcomes through non-market means, and recently there has been a tremendous increase in theoretical and empirical research on networks in the economics literature. One of these outcomes is for sure the contribution of networks to innovation and technological change in general, as it is now accepted that innovation is most effectively undertaken as a collective process in which networks play a central role.

The evolution of research on networks is characterized by contributions from a diverse range of disciplines including physics, mathematics, sociology, organization theory and management. It has become clear that interdisciplinary work on networks has a lot to offer to understand the processes behind networks and their influence. Research has become largely dispersed in the way different disciplines approach networks, although they share many commonalities in the core and influence each others' approaches as well.

Considering the largely diversified and rich research in the area of networks, this survey covers the recent literature on networks as far as they have implications for knowledge transfer among actors, innovation and technological change. Existing research mostly focuses on two types of networks as far as innovation is concerned; inter-firm and intra-firm networks, since these are accepted to have the most important impact on knowledge dissemination and innovation.

Recently, a general theoretical framework has emerged, combining game theory and graph theory[1] and which questions the influence of networks and how they are formed. Theoretical work has been accompanied by empirical research, mostly using social network analysis tools to understand in detail the processes behind network formation and their impact on the economy. In this review, we focus on the empirical literature, and we investigate what the role of both inter-firm and intra-firm networks have been in the innovation process according to the literature.

In this sense, topics covered include the effect of networks on fostering innovative capabilities; effect of social networks on knowledge transfer within a firm or among firms, on manager and employee performance, in improving the capabilities of firms; how the network structure and position of the firm or

[1] For the earliest work in this field, see for example Jackson and Wolinsky (1996)

individual influences performance as taken in various ways (innovativeness, creativity, perception of success and the like); the role of network in new product development and also process innovation; how networks effect organizational learning, establishment of routines and adaptation to the environment. Perceiving an organization as a network is important because it enables to explore how the pattern of relationships among actors within the organization influences the actors in the network, in a direct and/or an indirect way. In particular, the majority of the literature that we cover is directly or indirectly concerned with the implications of networking on agents' performance and/or behavior.

One important conclusion that can be derived from the survey is that, although there is a tremendous increase in network research, it is still difficult in most cases to draw robust conclusions and generalizable results. This is because the great majority of the studies focus on different sectors under different conditions, and define networks in different ways. Therefore, one of the aims of this survey is to highlight those areas in which some consensus has been achieved in the literature, and others which need more attention and research in the future.

The survey is organized as follows. In the first part, we cover the literature on networks of firms. In this section, we first look at how networks are addressed in the modern theories of the firm, namely transaction cost economics. Secondly, we investigate the literature dealing with how networks influence the behaviour of the firms as well as their performance. Then, we focus on the literature on geographical districts and networks. The first part finalizes with the discussion on the studies that relate technology /knowledge bases and networks. Second part of the paper reviews the research on intrafirm networks. Here we investigate how networks inside the firm influences knowledge transfer, creativity, employee and firm performance in general. Some concluding remarks follow.

2. THE INDUSTRY AS A NETWORK

The domain of interactions among firms in the economy can take countless forms, ranging from legal ownership agreements to informal know how trading. A major process that accompanies the inter-firm relations is mostly the significant knowledge flow that takes place between the actors, which is an important engine for innovation. These knowledge spillovers are not only caused by formalized arrangements between firms, but are also the result of informal communications among them, as in the form of collective invention (Allen, 1983). As firms rely more on external collaboration, the boundaries of the firms get blurred, and the firm becomes a dense collection of communication links within a larger network through which there is continuous knowledge flow. In the literature, inter-firm networks have been called in many different ways, each focusing on particular aspects but sharing many commonalities in the core.

Some examples are business groups (Granovetter, 1998) which refer to the group of firms that are bound together in some formal or informal way, which is neither complete (like the case where firms consolidated into a legal single entity) nor weak (like in short term strategic alliances); the keiretsu in Japan, chaebol in Korea are the most prominent examples. Powell et al. (1996) use the term "networks of learning", where their emphasis is on the way networks facilitate organizational learning and act as the locus of innovation. Ring and Van De Van (1994) and Oliver (1990) use the term "cooperative inter-organizational relationships". Many other terms have also been used, including "networks of innovators" (DeBresson and Amesse, 1991), "network organization" (Miles and Snow, 1986), "strategic network" (Jarillo, 1988) and "interfirm networks" (Grandori and Soda, 1995). A somewhat more general term that incorporates not only firms but also other actors like public laboratories, research centers and regulatory bodies has been used by Callon (1998) in his term of "techno-economic networks". Despite the many different terms used, most of these studies investigate what Jones et al. (1997) call to be "network governance", and who define as: "a select, persistent and structured set of autonomous firms engaged in creating products or services based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard exchanges" (1997: p. 2).

Network approach enables a dynamic analysis, because the state of the network in one period influences the state of the system in subsequent periods, as a result of a dynamic process of experience accumulation and learning (Garcia-Pont and Nohria, 2002; Gulati, 1999; Powell et. al 1996). The structure of networks are thus in a state of continuous change, because the interactions among economic agents are governed by the network structure, and these exchanges also shape the network structure in subsequent periods. Network evolution is mainly the result of a systemic interaction between technological, social and institutional factors, and the emergence of networks is through self-organization, rather then being governed through exogenous events (Kogut, 2000). As Imai (1989) states for Japanese business groups, the network view is a process view in which the basic unit is not the firm or other economic agents acting in isolation but various economic agents acting in relation to each other.

Today the modern theory of the firm in economics is largely dominated by the transaction cost approach (TCE, as pioneered by Oliver Williamson) which in general consists of the analysis of two extreme governance modes as markets and firms. The more networks gained importance in literature the greater the need to understand their underlying mechanisms, which distinguishes them from markets on one hand and firms on the other. In other words, if markets are one type of economic exchange, and if firms are the other, then how can networks be explained? This question has occupied the agenda of many scholars in the beginning of network research two decades ago. In approaching this question, some scholars placed networks somewhere between markets and hierarchies and have attempted to explain their dynamics with TCE logic. Others, though have claimed that networks resulted of mechanisms in modern industries characterized by fast innovation, uncertainties and task complexity which underline the weaknesses of TCE in explaining alternative governance modes. Below, we provide the main points of this discussion.

2.1. TCE and networks

The coordination of economic exchange is based on two essential features of industrial systems: the boundary between markets and organizations; and the intra-firm organization. Neoclassical economics largely ignores both of these features, and reduces the firm to a representative profit-

maximizing unit, where the boundaries of firms are explained via economies of scale and scope. Modern theories of the firm are dominated by the transaction cost perspective, which traditionally focuses on the trade-off between markets versus firms. Firm formation in TCE view is explained by the "cost of using the price mechanism" (Coase, 1937), and firms exist to minimize the costs associated with transactions. Underlying TCE are two basic assumptions regarding the behaviour of economic agents. Firstly, agents are boundedly rational, and accordingly all complex contracts become unavoidably incomplete (Williamson, 1998). The second behavioural assumption is opportunism, that is "self-interest seeking guile" (Williamson, 1975). The opportunistic behaviour is important since "attenuating the ex post hazards of opportunism by ex ante choice of governance" is mainly what the transaction cost approach deals with (Williamson, 1998: 31).

From a TCE perspective, the network-based firm appears to be a hybrid type of organization between markets and hierarchies (Thorelli, 1986; Williamson, 1991). On the other hand, some arguments have been developed favoring the view of networks as a distinct form that cannot be explained with a market vs. hierarchy view of exchange. According to this view, networks have distinct characteristics regarding for example, the feature of the items exchanged, or the behavioural attributes of parties involved in transactions which makes them theoretically infeasible to handle with the market vs. hierarchy approaches (Larson 1992; Powell 1990). When there is rapid economic and technological change, the transaction cost approach is a static cost trade-off analysis and cannot be used to explain the dynamic gains from networks (De Bresson and Amesse, 1991; Langlois, 1989; Notebooom, 1992; Powell et. al 1996). One may categorize the criticisms to TCE into three broad categories; the first one concerned with opportunism, the second one with the need for a more dynamic approach to understand networks in environments of rapid change and the third one the lack of social processes in TCE.

One of the central questions about the issue of opportunism is, whether the central behavioural assumption of opportunism in TCE can be reconciled with the development of mutual trust underlying long term relations in network organizations? For example according to Nooteboom et al. (1997), there is a polarization in the literature, since some scholars tend to focus on opportunism whereas others on trust, with few exceptions taking both into account. However, for a coherent approach to the network based organization, a reconciliation of the two poles is needed. This also relates to the lack of a dynamic

perspective in transaction cost approaches, as well as to undermined social contexts in which most economic relations are embedded in (Jones et al., 1997). In other words, as the transaction relation proceeds, there can be a change in the perceived risk of opportunism, and ex-ante expectation of opportunism may be replaced by mutual trust (or mistrust) as individuals accumulate experience in a social context (Nooteboom et. al 1997). The central role of opportunism in TCE shifts the attention away from the trust as a product of embeddedness of economic relations in social contexts (Uzzi, 1997, Noorderhaven, 1996; Johansson and Mattson, 1987; Larson 1992; Jones et. al, 1997). One of the driving forces in network forms being the mutual trust among parties, it is likely to reduce transaction costs[2] and improve performance (Carson et al., 2003).

Several researchers have carried out studies to incorporate social mechanisms within a TCE framework (Ybarra and Wiersema, 1999; Jones et al., 1997). From a transaction cost perspective, the selection of a partner is a trade-off between the costs of the risk involved in finding a reliable partner, (so that the risk of opportunistic behaviour is reduced), versus the gains from access to new opportunities. But essentially, the idea of a network of firms reduces the costs of opportunistic behaviour on the side of partners. In the case of informal know how trading systems, decisions to trade proprietary know-how are made by individual and knowledgeable engineers, "no elaborate evaluation of relative rents or seeking of approvals from firm bureaucracies are involved" (Von Hippel, 1989: 171) thereby involving less transaction costs (Von Hippel, 1989). In this way, network forms mitigate transaction costs, making opportunism more costly due to reputation effects in a tightly bounded social environment (Gulati et al. 2000; Walker et. al, 1997; Uzzi, 1997).

Finally, the exclusive focus of TCE on minimisation of costs disregards the strategy and organizational learning aspects of networking as well as social contexts (Eisenhardt and Schoonhaven, 1996; Powell et al., 1996). Kogut (1988) underlines the difference between a TCE approach and a strategy approach to joint ventures. In particular, strategy is related with the positioning of the firm vis a vis its rivals, whereas transaction cost approach focuses on the costs of transactions solely. Most of the time the motives underlying the formation of alliances are more complex than mere cost considerations, and factors like transfer of know-how among parties, accessing other firms' capabilities, and/or improving

[2] Noorderhaven, 1996; Gulati et al, 2000; Uzzi 1997; Jarillo 1988, and Dyer and Chu, 2003 for a direct

the firms' own capabilities via organizational learning are very important. As we argue in the following section, these issues have been a popular research agenda since they relate to networks.

There exist a rich literature that is concerned with *behavioural* attributes of firms as far as networking is concerned. Here, some of the questions addressed are, why firms enter into alliances and how do firms select their partners? how do the position of a firm in a network effects its future choice of partners? how do the capabilities of firms effected by alliances, and what is the relation between organizational learning and alliances of the firm?

Another strand of research takes into account the relation between the *performance* of the firm and its network (as performance is taken in many different ways). In this survey a focus is placed on the physical characteristics of the network (its structure) and /or the position of the firm in this network, and how these influence the performance of the firm. We will review both strands of literature in return.

2.2. Networks and Behaviour of the Firm: Why do firms enter into networks?

Many studies have attempted to explore the underlying motives for firms to collaborate with each other in various forms. For example, according to Hagedoorn (1993) the most significant three motives are technological complementarities (more important in sectors where interrelatedness and complexity is high), market access, and reduction of the innovation period (more valid for relatively mature industries). The 6 underlying motives for the establishment of inter-organizational relations as summarised by Oliver (1990) is perhaps the best categorization in this context. It is applicable to a wide range of motivations that underlie the networking activities of firms: a) necessity in the sense of meeting legal or regularity requirements, b) asymmetry, referring to the potential of an organization to exercise power or control over another organization, c) reciprocity, referring to the collaboration, cooperation rather than the exercise of power (horizontal linkages rather than vertical) d) efficiency, in terms of increasing the internal input-output ratio of the organization, e) stability, as an adaptive response to environmental uncertainties, f) legitimacy, to improve reputation, image, prestige. It is important to note that the intensity of each of these in the mix of motives varies according to the type of collaborative

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empirical test among US, Japanese and Korean firms.

activity and relatedly the features of the industry. For example, in uncertain and competitive environments, reciprocity and stability are important and in another example of joint ventures, or biotechnology there is for sure the effect of the motive of asymmetry, where larger firms exercise organizational control over smaller firms (Kogut, 1988).

2.2.1.Interdependencies in Resources

The earliest and the most widespread approach to explain why firms form collaborations and with whom, is the resource based approach. The resource-based view (Wernerfelt, 1984) explains collaborations among firms with respect to the complementarities in firm resources. According to this view, the firm is a bundle of resources and the most common motive for collaborative relations is the interdependence in resources. This means that firms form alliances with other firms because they are not self sufficient, and they collaborate to reduce uncertainty as well as to access each others resources (Pfeffer and Salancik, 1978) especially in technologically intensive industries (Hagedoorn, 1993). For example, in biotechnology the complexity and multidisciplinary character of the knowledge base are considered to be the main factors that draw firms into external collaboration (Arora and Gambardella, 1994; Hagedoorn 1993). The knowledge base is widely dispersed and the collaborations are mostly characterized by the alliances among the large and established pharmaceutical firms, which offer market access opportunities, and small firms' scientific and technical contributions.(Arora and Gambardella 1990, Walker et al., 1997; Shan et al., 1994) . Arora and Gambardella (1994) distinguish between scientific capabilities and technological capabilities, more specifically the ones applicable to the biotechnology sector, since it is highly science driven. The former is related with the ability of the firm to evaluate external knowledge. On the other hand the latter refers to the ability of the firm to utilize external knowledge. They investigate the relation between these capabilities and the value of external collaboration. Their results indicate that scientific capabilities reduce the number of collaborative agreements since large firms become more selective, whereas technological capabilities increase the number of collaborative agreements.

There is a large body of empirical literature on the motives underlying collaboration adopting a resource-based perspective.[3] In a leading paper, Eisenhardt and Schoonhaven (1996) analyse the semiconductor industry and adopt a resource-based and social perspective to understand the motives underlying alliances. According to them, firms in vulnerable strategic positions (emergent or growing firms, or firms facing many competitors) tend to form more alliances, as well as those firms with a socially strong management team. In a more recent study, Miotti and Sachwald (2003) adopt a resource based perspective to investigate the effect of complementarities in resources among collaborations formed by a wider range of actors, including academic institutions, firms, rival firms, clients, etc.

According to Gulati (1999), resource interdependencies and uncertain environments are necessary but not sufficient conditions for collaborative relations (Gulati and Gargiolo, 1998; Gulati, 1999). In other words, not all opportunities for collaboration result in an alliance, and thus one should take into account the social networks of firms as well in investigating collaboration patterns. There is a growing body of research to verify this postulate. For example, Gulati (1995) studies the collaboration patterns of firms in various industries, and finds that the likelihood of collaboration between two firms increases as the commonly known third parties between two firms is larger. He perceives the network to be a vehicle to carry information among the members about the reliability and capabilities of others (see also Shan et al., 1992). In another paper Gulati (1999) develops the concept of a network resource of the firm (measured by the centrality of the firm in its network), and he investigates how this influences the collaboration patterns of the firm. He finds out that central firms in their social networks are more likely to enter into alliances.

It is now accepted that network itself is also a resource of the firm (Kogut, 2000). Kogut uses the term "networks of knowledge" to connote capabilities that augment the value of the firm, achieved mainly through coordination while Gulati (1999) develops the concept of a "network resource" which is the value of the firm's connections.

[3] Also see Das and Teng (2000) for a review of existing approaches in resource-based view in relation to

2.2.2. Organizational Learning

Another strand of research gives the process of organizational learning a central role in explaining alliances. The pioneering paper in this literature has been that of Powell et al. (1996). They state that firms network with each other not only because they lack resources and need to access others, but because they seek to explore and exploit knowledge bases. In particular, their seminal work in biotechnology places the concept of organizational learning at the heart of the networks literature. Distinguishing between exploration and exploitation in organizational learning, the former refers to "experimentation with new alternatives", and the latter to the exercise of "refinement and extension of existing competencies, technologies and paradigms" (March, 1991: 85). Viewed in this way, "organizational learning is both a function of access to new knowledge, and the capabilities for utilizing and building on such knowledge" (Powell et al., 1996: 118). Network forms of organization enable firms to effectively explore new knowledge. Still, external collaboration is complementary to internal capabilities in the sense that they facilitate exploiting and building upon existing knowledge (Mowery and Rosenberg, 1989). Collaboration between firms not only enhances learning about new developments, but also strengthens internal competencies and thus the "locus of innovation" is found in the "networks of learning" (Powell et al., 1996) .

Organizational learning is usually embedded in the routines developed to effectively store, transfer, and develop knowledge in firms (Nelson and Winter, 1982; Cohen and Levinthal, 1990; Malerba, 1992). In this context, the recent decade have witnessed a surge of interest in exploring how inter firm networks contribute to organizational learning. Among these, Dyer and Nobeoka (2000) study the Toyota network, and how it enhances the organizational learning of its members. [4] Bogenrieder (2002) explores the process of sociocognitive conflict which refers to diversity among agents and the maintenance of a social environment to resolve this and identifies different types of social networks that foster learning in organizations under different problem solving cases.

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alliances.

2.2.3.Mimetic Isomorphism, Imitation

The role of social networks of firms are also mentioned frequently in the spread of certain organizational forms and to explain why firms form alliances. Therefore, within this literature the main idea is that firms form alliances not only because of lack of resources, or organizational learning or because of strategic considerations, but also they are embedded in certain social networks. Networks provide a feedback mechanism among the firms through time, which facilitates the spread of certain organizational forms. The concept of "mimetic isomorphism" was first put forward by Di Maggio and Powell (1983), and in the context of alliances this might be an important explanation (Kogut, 1988). This phenomenon has been studied systematically by various scholars in relation to network structure and/or embeddedness perspectives.[5] For competitive advantage, firms imitate the behaviour of other firms, so that the emergence of certain organizational structures happens through a positive feedback mechanism conferred by networks (Garcia Pont and Nohria, 2002). At the same time, firms' position within the network give an insight into the structural similarities among them. More specifically, firms are more likely to be influenced by other firms having similar structural locations, as revealed by their position within the network; like membership in the same clique, or having similar centrality measures in the network. In their dynamic analysis of the automotive industry Garcia Pont and Nohria (2002) find support for the hypothesis of "local mimetism" as an important motive for alliance formation. As the number of prior alliances increase, the competitive pressure on similar firms to do the same also increases and so is their likelihood to be involved in collaboration. Partitioning the firms in the network to strategic groups (as in Nohria and Garcia Pont, 1991), they measure the effect of similarity by the local network density of strategic groups.

Another strand of research investigates how managers' behaviour is influenced by their social network in which they are embedded, and find that managers are mostly influenced by their social

[4] They underline three knowledge sharing dilemmas (resistance to share proprietary knowledge, free rider problem and maintaining efficiency at knowledge sharing provided in the network) and explore the specific processes set by the Toyota network to overcome these.

[5] For example, Kenis and Knoke (2002) translate the idea of the organizational field to network of firms, and list a set of testable propositions on how the structure of this network will influence the patterns of tie formation among the members.

networks. This field of research is very rich, a pioneering work being Galaskiewicz and Wasserman (1989) who find empirical evidence that managers tend to follow the behaviour of others in their social networks when making decisions about donations to charity organizations. A more recent one, by Mc Donald and Westhpal (2003) finds evidence among the CEO of American companies that in response to a poor performance of the firm, managers tend to seek advice from executives of other firms who are their friends, or who are in similar positions as theirs.

A strand of literature that relates to network structure and firm performance, has been inspired by the seminal papers of Granovetter (1973, 1985). The "embeddedness" perspective tries to understand performance differences among firms in relation to the influence of social networks in which they are embedded in. Their position within these social networks have implications for their performance. In this strand of research, social network analysis tools are increasingly being utilised to gain an insight into the network position of a firm. The next section explores this strand of research.

2.3. Networks and the Performance of the Firm

In this section we focus on the issue of networks and performance of firms. Bulk of the research in this field is concerned with the physical characteristics of the network (or the position of the firm in the network) and how it relates to various performance measures. How this can take place is investigated in a unifying way by Gulati et al. (2000) who postulate that differential profitability of firms may be explained by the structure of firms within the network and that network concepts can and should be used in strategy research. The network perspective enables to model the explicit mechanisms through which knowledge is endogenously created and diffused within the industrial system and thus the structure of the network influences the extent of knowledge diffusion in the industry (Cowan and Jonard, 2003; Cowan, Jonard and Zimmerman, 2001) as well as how value is distributed among the firms in a network (Kogut 2000).

2.3.1. Embeddedness and Performance

The effect of embeddedness on performance has been widely explored in the empirical literature, and most studies have emphasized the positive influence of embeddedness on various criteria of performance. In one of the recent studies, Echols and Tsai (2005) investigate the venture capital firms and find out that the effect of the firm's strength of niche on its performance depends on the extent to which the firm is embedded in a network. The distinctiveness of its niche has a positive effect on performance when the firm is more embedded. In another paper, Andersson et al. (2002) find that in the case of multinationals, both technical embeddedness and business embeddedness have a positive impact on subsidiary performance. The concept of network transitivity has been tested empirically by Uzzi and Gillespie (2002). They investigate the relations between firms and their banks, and notably investigate how competencies in a dual collaboration are transferred to third parties in the network. They find that financial performance is better when firms have socially embedded ties with their banks.

In this field, one of the focal papers is Uzzi's (1997) study of the New York fashion industry, and looks into the probable negative effects of embeddedness. He highlights what he terms to be the paradox of embeddedness: "the same processes by which embeddedness creates a requisite fit with the current environment can paradoxically reduce an organization ability to adapt" mainly by decreasing diversity, reduction of non redundant ties and sometimes causing overembeddedness. He mentions the conditions under which embeddedness proves to be increasing efficiency as well as the conditions under which it can turn into a rigidity. This allows him to postulate that ties composed of a mix of arms length and embedded ties are more conducive to increased performance in the apparel industry.

2.3.2.Social Capital, Structural Holes and Performance

Recent years have witnessed an extensive amount of research effort devoted to the concepts of structural holes (Burt, 1992) and social capital (Coleman 1988), how these are reflected in the networks surrounding the firm, and how they influence performance. Burt (1992) argues that the competitive advantage of firms rests on their ability to fill structural holes between dense groups of firms. Low

structural holes, and therefore high level of redundancy in ties make information exchange inefficient and thus not beneficial for competitive advantage. Walker et al. (1997), in their seminal paper on biotechnology, translate the ideas of structural holes and social capital into network language, and express that it is the firm's position in the network which determines its access to social capital. They identify high levels of social capital with dense networks, and as for the structural holes, they state that "network positions with the highest income lie between not within dense regions of relationships" (Walker et al., 1997). In the case of biotechnology, they find that the social capital is a better predictor than structural holes in the patterns of relationships. According to the structural holes perspective, the critical importance of filling structural holes to avoid redundancy in knowledge flow is underlined. Conversely, Coleman (1988) argues that taking place in a dense network with cohesive ties confers competitive advantage to the firm, because coordination is improved through repeated exchange with stable partners which facilitates the transfer of tacit knowledge.

Social capital versus structural holes are analogous to the strong ties versus weak ties conceptualization of Granovetter (1973), respectively. Strong ties are usually associated with thick information exchange, efficient and effective transfer of tacit knowledge, and connote trust among partners. In this sense, strong ties are better to exploit existing knowledge, and to deepen the knowledge of the firm in specific areas (Rowley et al., 2000; Uzzi, 1996). On the other hand, weak ties are associated with exploration, that is access to new areas of knowledge (Granovetter, 1973, Dyer and Nobeoka, 2000; Rowley et al., 2000). These two opposing views on the structure of networks have provoked increased empirical attention in the last decade as we review below.[6]

One of the research in this field was carried out by Ahuja (2000) where he examines how the position of the firm within the network influences its innovative output with a longitudinal study in the international chemicals industry. There are two kinds of benefits that a firm acquires through networks. First of all, firms access the resources (physical, skills, knowledge) of other firms, and second, networks enhance firms access to outside developments, like a major technological innovation, or failures through

[6] See Borgatti and Jones (1998) for various ways in which structural holes an social capital can be measured in networks.

knowledge spillovers. His findings suggest that structural holes have a negative impact on innovative output; indirect ties (enhancing knowledge spillovers, without costs of maintaining links) and direct ties (enhancing both access to resources and knowledge spillovers) have a positive effect on innovative output of the firm. In a similar framework, Hite and Hesterly (2001) analyse how the changing resource needs of start-ups matches with the cohesive ties or structural holes in various stages of evolution of the firm. In particular, they state that as the firm passes from the emergent to a growing stage, the network shifts in response to changing resource needs. In initial phases, the network structure conducive to success is more cohesive and as the firm grows filling structural holes becomes more critical for success. McEvily and Zaheer (1999) study metal working work shops and find evidence in favor of bridging ties for competitive advantage, which are non redundant, infrequent and geographically dispersed.

Other studies focus on different aspects of the debate. Among these, Gargiulo and Benassi (2000) stress the trade-off between the safety conferred by cohesive ties and the flexibility conferred by filling structural holes. Bogenrieder (2002) focuses on organizational learning, and stresses that depending on the type of uncertainty and problem, different network architectures are conducive to better learning, for example underlining that weak ties are better for assuring cognitive diversity. Bekkers et al. (2002) relate the small world perspective to structural holes versus empirical social capital arguments. Specifically, while Burt's structural hole view can be associated with more random structures where path length is approaching minimum, Coleman's social capital perspective refers to local networks with high cliquishness. They find evidence of small world properties in technological alliances.

Inkpen and Tsang (2005) focus on different networks (cluster, intracooperation and strategic alliances) and investigate how knowledge transfer can be facilitated in different types of networks with respect to different dimensions of social capital. In the case of global steel industry, Koka and Prescott (2002) outline also different dimensions of social capital and demonstrate that each dimension has a different impact on firm performance (information dimensions, like volume, diversity and richness).

The conflicting results of these studies which predict different best structures for different industries reveal that the effect of strong ties and weak ties on firm performance depends largely on the conditions surrounding the firm. Rowley et al. (2000) investigate the conditions under which strong/ weak ties and close/ sparse networks are associated with firm performance. Their findings for semiconductor

and steel industries reveal that weak ties are beneficial for exploration, especially in uncertain technological environments, and that strong ties are beneficial for exploitation, where uncertainty is low and competitive pressure is high. Dyer and Nobeoka's (2000) detailed study of the Toyota network also supports this argument.

2.3.3.Other studies on network structure and firm performance

Some other studies on the relation between network structure and firm performance include, Bae and Gargiulo (2004), on the US telecommunications industry, which analyse the effect of structure of the alliance network and partner substitutability on firm profitability. When the focal firm has a large proportion of powerful partners, its control over resources can also be costly for the firm, which might outweigh the benefits of an alliance. When this is the case, a dense alliance network structure is better for firm profitability.

Tsai (2001) carries out an empirical study in petrochemicals and food manufacturing, and finds that it is the interaction between absorptive capability and network position that has a significant effect on innovative performance. Singh and Mitchell (2005) find out that both entry and post entry collaboration contribute to superior performance, the extent of which is dependent upon who the collaborator is and upon the size of the firm in hospital software industry.

These imply that firms may use their collaborative agreements as a strategic move to improve their network positions, which was a question addressed by Baum et al. (2003). In this paper, the authors study Canadian investment bank networks to highlight the extent to which the structure of the network is emergent, and to what extent it is shaped by strategic decisions of core and peripheral firms to improve their network positions.

2.3.4.Sucess and Failure of Alliances

One of the fields of research in strategic alliances literature investigates why some alliances are successful while others fail, given that more than half of alliances fail.[7] Mostly, reasons of failure include,

[7] See for example Das and Teng, 2000; Madhok and Tallman, 1998; Park and Ungson, 2001.

prioritization of individual interests over collaborative interests, an internal tension between cooperation versus competition, rigidity versus flexibility and short term versus long term orientation. There is a range of studies that focus on the relation between the success of the alliance and its scope, which we review in section (see for example, Khanna, 1998, Oxley and Sampson, 2004 and Mowery et al., 1998).

Hoang and Rothaermel (2005) analyse alliance performance in biotechnology and conclude that organizational learning through diverse range of partners results in higher performance then repeated alliance experience with a single partner. A similar result was obtained by Beckman and Haunschild (2002) who find that firm's acquisition performance increases when its network partners are diverse in their experiences. Baum et al. (2000) analyse the performance of start-ups with respect to their alliance formation with others, having defined network efficiency by the diversity in the firms partners (universities, research institutes, rivals, etc.) Their results indicate that diversity in the partners competencies increases start-up performance in most aspects. In the case of biotechnology Zollo et al. (2002) use the evolutionary concept of routine to understand whether the routinization contributes to the performance of a strategic alliance, and find a positive effect. However, in the case of multinationals, Goerzen and Beamish (2005) findings contradict with these studies. According to them, multinational economics performance is lower when the alliance network is composed of diverse partners.

2.4. Networks and Geographical Districts

In this part, we focus on regional districts, as well as the line of research that underlines the significance of social contexts in economic outcomes in general.

One of the major themes that has been studied in depth is the issue of trust in interfirm relations. For business groups, Granovetter states that whether the source of trust is family ties as in the case of Korean chaebol, or whether it is geographical proximity, there is always a "cognitive marker around which actors may construct trust relations at higher intensity than with those outside the category" (1998: 84).Trust developed through interacting is a "cumulative product of repeated past interactions" (Ring and Van de Van, 1994). To the extent that knowledge is tacit and only partly codifiable, face-to-face interaction becomes one of the most efficient ways to ensure its diffusion, moreover facilitating the

development of trust between the parties. The embeddedness of economic relations within social relations has significant effects on knowledge creation and diffusion, especially in geographical clusters. These social networks have a positive effect on the extent of performance, and underlying them the most significant mechanism is trust (Jones et al., 1997; Lazerson, 1995). Even in cases where there is legally a binding agreement, either within geographical clusters or among globally dispersed firms, these are accompanied with social mechanisms that permit parties to develop a common language through time so that knowledge transfer is facilitated. Previous empirical research has confirmed that face-to-face contacts and geographical proximity are important factors facilitating the diffusion of innovations (Jaffe et al., 1993). Nevertheless, recent empirical research shows that social connectedness might be more important than the mere geographical proximity (Balconi et al., 2004; Sorenson, 2003; Agrawal et al., 2003).

For example, the distinction between an industrial district and a network is underlined by Lechner and Dowling (1999), who stress that the existence of close ties among actors and social networks are the basis of regional networks. This distinction has important policy implications, since for the success of an industrial district not only the existence of a regional infrastructure, pooled skill, common legal and financial services are adequate; important part of success stories arises from cultural factors, and reveal the importance of social networks within regions. Through social networks, knowledge of diverse actors is integrated. Innovative actors mostly form a closed community, and much of the new knowledge they generate is enabled by the transmission of knowledge across among the social communities of experts, knowledge which is not accessible by outsiders.

The structure of the networks formed by innovative actors obviously has implications for the innovative potential of the economy, mainly in terms of their impact on the rate of knowledge diffusion, efficiency with which diverse and complementary skills of other actors are accessed, or in terms of effective transmission when knowledge is tacit. Also the structure of these networks shows the extent to which innovative actors are connected to each other and have access to each others knowledge. It is important to point out that effective networks should prevent the fragmentation of knowledge groups and duplication in research efforts.

Nevertheless, it has been argued in recent years that there is a trade-off between the advantages conferred by face-to-face contacts exchanging tacit knowledge in regional districts, and the use of

communication technologies providing fast and cheap access to distant sources of information via exchanging codified knowledge. The question is, are face to face contacts still important in the face of rapidly developing ICT? In the case of Italian districts, Chiarvesio et al. (2004) carry out an empirical study, and underline the complementarities between localized communication and the use of ICTs. In the case of Austria, Kauffman et al. (2003) look at the effect of Internet on innovation networks and find out that Internet is actually fostering communication with local innovation networks. It is therefore more complementary to the existing innovation networks, than assisting firms to extend to totally new partnerships.

The increased collaboration between firms in Silicon Valley and the sharing of a common culture and social context in the region enabled to better foresee market conditions, shaping the rate and direction of technological developments to a large extent. On the other hand, firms in Route 128 were mostly self-sufficient vertical hierarchies, largely closed to external collaboration (Saxenian, 1994). Indeed, it has been shown in other studies that informal contacts have important influence on knowledge diffusion in regional clusters.[8]

Kogut (2000) views the emergence of a certain network structure not only as the result of industry characteristics, but also the result of an interplay between social and institutional norms, which clearly applies to the case of Silicon Valley. Diffusion within a district is a function of the combination of many factors like universities, start-ups, formal alliances and informal communications as well as mobility of tacit knowledge carrying engineers. One of the factors underlying the success of Silicon Valley is that the knowledge held by engineers had a highly tacit quality and that the environment supported their mobility of across the spatial boundaries (Almeida and Kogut, 1999). Although geographically bounded, Route 128 can hardly be considered as a regional network, and the organization structure is largely centralized in Route 128 with large established firms occupying central positions with limited mobility.

[8] See for example Dahl and Pederson, (2004) for the case of regional cluster of wireless communication firms in Northern Denmark; Bowles and Gintis (2004) who look at the economic effects of ethnic and religious sharing of identity in business networks and find support for the idea that these networks can solve economic problems that are resistant to market or state based processes and Owen-Smith and Powell (2004) in their study of the Boston metropolitan area find support that informal transmission mechanisms strengthens the information channels among physically proximate firms.

Another strand of literature has approached networks from a wider context including not only firms but also research institutes, universities, and government bodies as well. Among these, Kali (1999) studies the role of business networks as substitutes for the legal system in transition economies. Hites and Hesterly (2001) study the relations of firms with regional institutes in metal working job shops, Collinson and Gregson (2003) compare the three organizations established in USA, UK and Canada to promote new start-ups and the way they interact with networks of firms and other institutions in their respective regions.

Based on the foregoing arguments, it is now accepted that social networks are important vehicles to foster innovation, but empirical work in this area is still in its infancy, mainly because of the difficulties in detecting social networks of inventors on a large scale (Breschi and Lissoni, 2003). One promising avenue in the detection of these networks has been shown to be patent data analysis, because it provides information on co-invention and citation patterns among patents. The literature on networks and patent studies is reviewed in the next section.

2.5.Technology, knowledge base and networks

Adopting a network perspective enables constructing the mutual relation between the pattern of technological development and networks of economic agents. The emergence of a certain network structure is usually a function of specific industry settings (Kogut, 2000) and networks also influence the way technology evolves (Soh and Roberts, 2000). One of the earlier works to demonstrate the mutual relation between technology and networks is by Barley (1990) who shows how the characteristics of technology also change and modify social networks in an organization. [9] This is a field of research that has been gaining attention only recently in the literature.

Some of the later work consist of econometric models, like Powell et al. (1996) and Walker et al. (1997) who find evidence of a path dependent learning process specific to biotechnology industry that shapes the network of relations among firms. More recent studies can be categorized under different headings. For example, one strand of literature deals with knowledge bases and network structure. Among

[9] Also see Burkhardt and Brass (1990) on how technology effects network structure.

these, Orsenigo et al. (1998, 2000) construct a relation between the dynamics of the knowledge base in biotechnology, and the evolution of the industry, and detect a close relation between the two. More specifically, their findings point to the fact that the hierarchical structure of a network of firms can be perceived as an adaptive response to the hierarchical structure of the knowledge base (with more generic theories on top of hierarchy, each leading to branches applicable to specific areas). McKelvey et al. (2003) investigate the biotechnology as a sectoral system of innovation, and explore in detail the historical evolution of the network of relations, as well as how these were shaped by the evolution of the knowledge base, regulatory environment and the market. Ozman (2005) studies the breadth and depth of knowledge bases and how they relate to the organizational structure of an industry as expressed as a network. Cowan et al. (2003) explore the effects of interaction in networks compared to no-networks (no structure in communications). Their simulation results indicate that regular structures generate higher knowledge growth in industries with tacit knowledge and high technological opportunities, whereas when knowledge is codified and technological opportunities are lower, communication without any structure performs better.

Closely related to this strand of research are the studies that focus on complexity of the knowledge base (for example see Kash and Rycroft, 2000). Among these are Frenken (2000) who uses Kauffman's NK model to show complementarities among technologies in the aircraft industry. Particularly in complex product systems, complementarities among the components render inter-organizational networking (or networking among the units within the firm) necessary for competitive advantage and timeliness. Brusoni et al. (2001) stress the role of the firm as a systems integrator in complex product systems, specifically in the case of aircrafts. Systems integrators, while outsourcing manufacturing and design to specialized firms, maintain the system integration capabilities to coordinate a loosely coupled network organization. Another paper linking complexity and networks is by Sorenson et al. (2003). In this paper, they analyse the relation between the value of access to knowledge (value defined in terms of the effect on knowledge reproduction) and the interdependence among components of it. They utilise patent data to depict that, when knowledge is very little or highly complex, distant or close recipients to the knowledge derive equal value from it. However, at intermediate levels of complexity, maximum benefit is achieved by closer recipients of knowledge.

As stated previously, one of the conditions in which firms need to increase their collaborative links is when there is uncertainty in the environment. For example, in the context of alliance formation patterns, Beckman et al. (2004) demonstrate in the case of largest US firms that, whether new types of partners (for exploration) or stable old ones (for exploitation) are selected depends on the type of uncertainty the firm is facing. In the context of new product development, Rothermel and Deeds (2004) find in the biotechnology sector that exploration and exploitation alliances are used in different phases of a products life-cycle. There are a few empirical studies that aim to detect the relation between uncertainty and networks. Rosenkopf and Tushman (1998) examine the co-evolution of community networks and technology cycles in the flight simulation industry. They distinguish between eras of ferment, where technical uncertainty is high, and periods after which a dominant design emerges, which are the periods of incremental change. Their findings indicate that the intensity of the relations among actors increases during the former period, and they stress the mutual relation between technology and networks. Similar results are obtained by Pyka (2000), who investigates the emergence of informal networks and the stage in the industry life cycle. Another paper by Nesta and Mangematin (2002) relates network structure to industry life cycles in biotechnology. Their results indicate that when uncertainty is high, firms form more collaborations mainly to exploit knowledge. In maturity, exploitation gains importance and firms revert to internal learning mechanisms. In a slightly different framework, Madhavan et al. (1998) study how specific industry events shape the structure of the network in the steel industry. They measure structure by centrality and interblock relations, and focus on industry specific events like a major technological change, entry of a powerful competitor, a change in the regulatory infrastructure, and dramatic shifts in consumer preferences.

Among other studies are Stuart and Podolny (1996) who model firms technological positioning as a network, and provide a grouping of firms in Japanese semiconductor industry based on their technological positions. As for Stuart (1998) he places the newly established firms on the technology space (the more overlapping competencies firms have, the closer they are), and investigates how distance influences future alliances. According to his results, prestige and closeness increases the possibility of future alliances. Mowery et al. (1998) investigate the transfer of firm capabilities by looking at firm capabilities and at the level of technological similarities and complementarities before and after alliance

formation. Their findings indicate that the level of technological overlap increases after alliance formation, regardless of the initial motives underlying alliance (whether for market access or technological). However, Oxley and Sampson (2004) underline that when firms are competitors, the unintentional leakage in valuable technologies can also be a barrier to an R&D alliance. In the case of electronic and communication equipment companies, they find that a response to this case can be to limit the scope of the alliance and to regulate the knowledge flow.

It is now accepted that innovation is a cumulative and social process, and that interpersonal communication among scientists, engineers, or technologists play a vital role in the way knowledge diffuses. In this sense, individual inventors are the carriers of knowledge in their respective social networks. One promising avenue in the detection of these networks has been shown to be by using patent data, because it provides information on co-invention and citation patterns among patents. There has been recent attempts to use patent data to detect social networks, or to apply social network concepts to patent data. For example Balconi et al. (2004) use patent data to detect the structure of inventor networks formed by corporate researchers and academic inventors using Italian data. In another study, Singh (2003) investigates the relation between knowledge flow and the social distance between inventor teams, and finds that the existence of a social link between two teams is associated with larger knowledge flows. Findings by Rosenkopf et al. (2001) also support this argument. More precisely, they emphasize the importance of communication among mid-level managers within technical committees in cellular service providers. They state that when firms have less prior alliance experience, interpersonal communications among technical committees forge knowledge flow to a large extent, especially in the cases of the formation of future alliances and of partner selection.

3. FIRM AS A NETWORK

Network studies have accelerated due to the dramatic increase in inter-firm relations over recent decades, as suggested by the above literature. Nevertheless, research has accelerated not only in the field of inter-firm networks but in many other areas as well. One of these, which has important

implications for innovation and knowledge diffusion, has been the studies on intra-firm networks. In this strand of research, the firm is seen as a network of employees.

Empirical studies on the role of social networks within firms have gained importance in intra firm network studies because of their effect on knowledge diffusion and knowledge sharing. A general emerging consensus is that the harmony between the structure of these networks and the content of knowledge being transferred among people are very important for the effectiveness of knowledge sharing.

For example, a strand of research analyzes the characteristics of knowledge sources within the firm and how they relate to the network structure in the diffusion of knowledge. In general, a network structure that enables access to heterogeneous sources of knowledge within the firm seems to yield better performance. In a study of a multiunit electronic firm, Hansen (2002) finds that both network structure and knowledge relatedness are important for effective knowledge sharing. Specifically, when knowledge is codified, links might be redundant because they still involve maintenance costs, whereas for the transfer of tacit knowledge, knowledge relatedness between agents and the shortest path between them is important for efficiency of transfer. In another study in which he analyzes the effect of weak and strong ties in a multiunit company and their effect on new product development, Hansen (1999) finds that strong ties are better for the transfer of complex knowledge among subunits of a firm, and that weak ties are better in terms of searching for useful knowledge in other subunits, that is not complex. Rodan and Galunic (2004) emphasize the effect of both network structure and also access to heterogeneous knowledge sources in managerial innovation performance in a telecommunications company. Another study is by Reagans and Zuckerman (2001) who investigate network structures on corporate R&D teams and find that communication among diverse actors, as well as a dense network increases productivity. Birkinshaw (2002) discusses the structure of R&D units of companies, and argues that the way R&D units of multinationals are structured efficiently should depend on the features of knowledge assets of the firm. Reagans and Mc Evily (2003) explore in detail how the structure of networks influences the knowledge transfer process. They also underline the importance of the network range in terms of access to heterogeneous knowledge sources. They find that both social cohesion and network range ease knowledge transfer, and that their effect is stronger than the strength of a tie between people. Mehra et al. (2001) analyse how personality, network position and performance of an employee are related to each

other. More recently, Reagans, et al. (2004) compare the importance of network structure and of the demographic features of its members and investigate how these contribute to performance of the team. Tsai and Ghoshal (1998) find that social interactions and trust have a significant positive effect on resource exchange among the units of an electronics company, and that these in turn had a positive effect on innovation.

There is also a range of studies which look at the effect of centrality in groups and teams. According to Sparrowe et al. (2001) there is a positive relationship between centrality and performance. Klein et al. (2004) analyse how members become central actors in teams. Some other studies in this field look into the decentralization and hierarchical structures, how they emerge, or which one is better for performance under different conditions. For example, Rulke and Galaskiewicz (2000) study the effectiveness of both knowledge distribution and group structure in MBA group teams, and find that performance depends on the joint effect of both group structure (centralized or decentralized) and distribution of knowledge in the group. For centralized teams, generalist groups outperform specialist groups. Tsai (2002) looks at the efficiency of knowledge transfer within a firm and among subunits, and finds that when units compete for market share hierarchy has a significant negative effect, and that lateral knowledge sharing by informal contacts has a significant positive effect on knowledge sharing. As for Ahuja and Carley (2002), they perform an empirical study of the emergent structure of networks in a virtual organization. Unlike the traditional perception of decentralization and flexibility, their results indicate that in virtual networks, specialization of a limited number of agents can result in the emergence of hierarchical structures. Another strand of research deals with how networks relate to perceptions within the firm. Among these, Ibarra and Andrews (1993) look at how employee perceptions are shaped by network structure whereas Smith-Doerr et al. (2004) study the effect of networks on managers' perceptions of success and failure. Some other studies include, Roberson and Colquitt (2005) and Umphress et al. (2003), who study the perception of justice in groups and teams and Perry-Smith and Shalley (2003) focus on how networks are related to creativity of network members.

4. CONCLUDING REMARKS

In this paper, a recent survey of the literature on networks has been carried out. Taking into account the wide and diversified literature on networks, we focused on empirical research in two fields as they have implications for innovation and knowledge flow; we took industry as a network and the firm as a network. In the first case, networks are taken in an organizational context, in which the literature is concentrated mostly on inter-firm networks, analysing their implications for the behaviour and/or performance of individual firms. In the second case, we focused on the strand of research that focuses on networks within a firm and on how they contribute to the performance of the firm in terms of knowledge dissemination.

One of the results that seems to emerge from this survey is obvious to many scholars: networks have a very important role in innovation. However, more robust and refined results that are universally acceptable are yet difficult to achieve. This is because most of empirical network studies focus on different sectors, different conditions, and different types of networks, which makes it difficult to reach general conclusions supported by empirical evidence. Nevertheless, in this survey an effort has been made to draw a general picture of where network research stands at the moment, what kinds of results in which areas have already been achieved with consensus, and also to highlight those areas that need further research in the future.

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