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Dorothea Jansen

Networks, social capital and knowledge production

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Contents

1. Introduction

Knowledge, its use and production, today is seen as the central resource within societies and organizations. Modern societies are no longer characterized as industrial societies, but as knowledge societies; modern economies are knowledge-based economies.[1] Social and economic development and performance depend on the capacity of individuals and organizations for the continuous search for and exploitation of new knowledge, i.e. innovation.

Thus, not just corporate R&D, but the whole system of innovation including Higher Education and the state financed research system (Nelson 1987, 1993, Freeman 1988, Lundvall 1992, 2002), is evaluated from the point of view of its contribution to the production and diffusion of knowledge, to industrial innovation and the competitiveness of national or European industries. The central thesis underlying this paper is that innovative capacity and production of knowledge more and more depend on personal and organizational networks, today. New approaches to the theory of the firm claim that the superior-

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* This is the revised version of a paper that I presented at the research conference on "International Competitiveness And Innovative Capacity in Universities And Research Organizations – New Modes of Governance" in May 2001 at the FÖV, Speyer. This became the starting point for the building of a network of researchers with the aim of analysing the reforms in the German research system and their consequences for research conditions and performance. This research consortium was established by the German Research Association (DFG) in July 2003 and started research in fall 2003 (homepage http://www.dhv-speyer.de/jansen/forschung).

A research stay at the Interuniversity Consortium on Social Science Theory and Methodology at the University of Groningen, NL during summer 2003 gave me the time to come back to this unfinished manuscript. I acknowledge funding by the National Science Organization of the Netherlands and would like to thank people from the ICS Groningen for giving me such a stimulating research environment.

1 A knowledge based economy is characterized by the fact that the competitive edge of firms changed from price competition to towards continuous innovation and improvement (OECD 1998). Besides rapid change in goods and services it means that creation and management of change becomes a mission in itself and knowledge transactions become more important and more numerous (*Maskell* 2000, *Weingart* 2001).

ity of organizations over markets is due to their advantage in creating and sharing knowledge (Kogut/Zander 1992, 1996; Nonaka/Takeuchi 1995; Spender 1996, Foss 1999, Nelson/Winter 1982). But in fact, it is neither the firm or organization nor the market that can stimulate and co-ordinate the production of knowledge satisfactorily. Networks will become an additional and dominant mechanism balancing innovation and co-ordination.

First, I will deal with the concept of knowledge, types of knowledge and the knowledge process, as well as related concepts like innovation and learning. Second, I will spell out the argument about networks being a more sophisticated mechanism of co-ordination than either markets or organizations. I will introduce the concept of social capital that is embedded in social structure or networks. A social network approach can help to find out why and when which type of network structure and which network ties promote the process of knowledge production and innovation on the meso level of organizations. A central result of this discussion is that there is a trade-off in the benefits from either cohesive dense networks or sparse, far-reaching networks and weak ties bridging so called structural holes. In chapter 4 I will tackle the question which type of network structure will be better under which conditions for the knowledge process and review some empirical evidence. I will present some arguments on why an innovative network strategy in R&D will become more important under conditions of increasing interdependence and volatility. And I will deal with the question how the trade off between dense networks and structural holes and between innovation breeding incentives and trust breeding institutions is solved in networks. Finally, I will outline a more macro level interpretation of networks of knowledge production and innovation as a new governance form.

2. Knowledge, Innovation and Learning

Knowledge is more than information or data.[2] Knowledge delivers mental models of reality for individuals and organizations. It is endowed with experience, judgement and values. It depends on perspec-

2 Information is defined as data (signs + syntax) that are put into a context of a problem at hand. Knowledge is the goal oriented integration of several information elements (*Steinmüller* 1993: 236).

tives and goals (Huseman/Goodman 1999: 107; Rehäuser/Krcmar 1996: 5; Venzin et al. 1998: 44 ff.).

Knowledge comes in several types, it displays cognitive, economic and social dimensions. There used to be a rather strict line of differentiation between technical knowledge accumulated by crafts and professions and scientific knowledge developed by academic research. Technical work aims to produce working artifacts and is governed by technical rules, that is by inequalities and means-end-relations. Scientific activity instead strives for truth, scientific laws and equations. It accepts high uncertainties in the route to new knowledge with an open time scale. Scientists prefer simple systems and reduce reality to models with few elements and relations. Technologists on the other hand, prefer less risky ways to develop new applications within a shorter time perspective. But, technical knowledge is at the same time more complex and concatenated. It tries to represent a real world phenomenon in all varieties and synthesizes all available knowledge pieces (Sahal 1981, Rosenberg 1982, Pavitt 1991; Nelson/Rosenberg 1993, Faulkner 1994). Nelson (1989: 233) denotes this difference in openness/generality versus specificity of knowledge as "generity". Technology is specific in that it tries to spell out all those context variables that science ignores, but which are essential for effective functioning of an artifact or process. The aim of this endeavor is of course to buffer the artifact or process from potentially conflicting contexts, so that they can be operated by users without technological understanding (for instance when you drive your car or run your PC).

The sober line between science and technology today has become blurred in the cognitive, the social and the economic dimension. Beginning in the 19th century in the areas of chemicals and electrical engineering, industry became more and more science-based. Today, to mention a few science-based industries, these are not just typical high-tech industries like biotechnology and semiconductors, but also traditional industries like food processing, ceramics and mechanical engineering, and service sectors like transport and newspapers. The interaction between science and technology is particularly intense in areas where a scientific breakthrough leads to a change in a technological paradigm (Dosi 1988). Interaction, neither in the cognitive nor in the social sense, is a one-way street. Technical problems put serious scientific questions and scientific knowledge triggers technical application. All this today happens on an accelerated time scale. Time from discovery to markets are getting shorter and shorter. So called strategic research which produces the background knowledge required for the development of new technologies is conducted today not only in industry, but also in public sector science (Rosenberg 1990, Brooks 1994, Faulkner 1994, Gibbons et al. 1995; Schulz-Schaeffer et al. 1997, Jansen 1995a, 1996).

From an economic perspective, knowledge can be a public good type, it can be a private good or it can be a sort of collective asset of a group, an industry sector or a profession. Academic, scientific knowledge used to be a public good[3] while technical knowledge tended to be of a more private type, often protected by property rights (Schott 2001, Stiglitz 1999, Dasgupta/David 1994, Cowan/David/Foray 2000). Some technical knowledge is of course of a more generic type, not specific to products and processes of a particular firm. This knowledge pool is a collective asset of an industry sector, of professional and trade associations, and it is also developed by them and technical colleges etc. How to design a governance system that gives due credit to the use of commons of pre-existing knowledge is an open question. Another problem is that property rights to knowledge, while stimulating innovation, pose the danger of monopolistic positions which might block further innovations.

The protection of private knowledge in the firm is based – in addition to property rights – to a great deal on the cognitive characteristics

3 Knowledge, and particularly fundamental scientific knowledge used to be thought of as a pure public good. Since Arrow (1970) it is widely held that fundamental knowledge is not marketable, since nobody can be excluded from its use. Once you know the "product", you can use the knowledge "for free" and will not pay for it. Next, knowledge does not diminish when it is used, the consumption of knowledge does not bear the characteristic of rivalry in consumption. This state of affair used to legitimize public financing of basic research, since otherwise basic knowledge would be undersupplied.

But, this is not the whole story. Even knowledge as a public good cannot really be taken from the shelf and put to new applications without further investments by the user. And its potential value can only be recognized if a firm is involved in the knowledge process and the knowledge community producing this new knowledge. This is one of the causes for the increasing importance of non-market processes. The necessity to assure this absorptive capacity to some extent lowers the temptation for free-riding on the knowledge investments of other actors. In order to make use of their knowledge you must invest into its "absorption" and thereby you (inadvertently) contribute to the collective knowledge pool. This is behind the growing activities of industry in basic research.

of technical knowledge. Such knowledge is not only specific, thus it might not be of much value for other users (Nelson 1989). It is also tacit to a large degree (Polanyi 1962, 1966). Tacit or implicit knowledge is a sort of specific knowledge that is not spelled out. Tacit knowledge is difficult to codify, it is personal and contextual, cannot easily be aggregated or transferred. Explicit and codified knowledge instead is easily communicated and thus it is almost impossible to keep it private and secret.

With the advent of so-called strategic research the chance to predict the economic characteristics of knowledge from the organizational home of its producer changed dramatically as did the correlation between organizational home of producers and cognitive characteristics of knowledge. Today, industrial research groups conduct basic research and publish their results in the open literature and academic groups patent their result and sell it to companies. Summing up, with the strengthening of the interaction between science and technology came about a move towards interests in the specifics of an application and in its economic value on the side of academia, while industry acknowledges the need to conduct fundamental research which results in generic knowledge as a collective asset (Gibbons et al. 1995, Etzkovitz/Leydesdorff 1997 und 2000, Nowotny et al. 2001).

Table 1: Explicit and implicit knowledge on individual and collective level

Knowledge is:	*Individual*	*Social (Group, Organization)*
Explicit/ codified	Conscious concepts	Objectified stories, mission, rules, handbooks etc.
Implicit/ tacit	Automatic skills	Collective genres (how things are done around here)

(adapted from *Spender* 1996: 52; and *Cook/Brown*: 1999: 391; see also *Lam* 2000 and *Collins* 1993)

Considering the social base of knowledge, we have to take into account that knowledge can be of an individual or of an organizational/ collective type. Starting with individual knowledge, this type is stored in the brains and bodily skills of people. The theory of the firm and theories of organizational learning by now concede that organizations command knowledge, too. They know at once more and less than what their members know.[4] The difference between individual and organizational knowledge is mostly due to tacit organizational knowledge. This is embedded knowledge. It consists of shared metaphors and norms, knowledge about communicative and collaborative practices in an organization over and above encoded, explicit knowledge like official rules, blue prints and handbooks (Lam 2000; Nahapiet/Ghoshal 1998; Venzin et al. 1998).

Table 2: Types of Knowledge and Knowledge Conversion

	End point	
Starting point	Implicit	Explicit
Implicit	Socialization	Externalization
Explicit	Internalization	Combination

(*Nonaka/Takeuchi* 1995: 62)

Nonaka and Takeuchi (1995, Nonaka et al. 1998) analyzed the organization of knowledge by crossing the two types of knowledge as a starting point and as an end point. The process of codifying implicit knowledge via dialogue and reflection is named externalization. By socialization in an interactive process implicit knowledge is transferred from one individual or group to another. In internalization explicit knowledge is applied to new contexts. This learning by doing yields new contextual, implicit knowledge on an operational level. Finally, combination puts pieces of explicit knowledge together.[5] Especially the process of externalization is highlighted as a process of creating new knowledge for the corporation.

The advantage of codifying implicit knowledge to turn it into explicit knowledge is very much debated. Mueller (1999) points to the

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4 *Hedberg* 1981, *Nelson/Winter* 1977, 1982, *Argyris/Schön* 1978; *March/Olsen* 1976; *Levitt/March* 1988, *Simon* 1991; *Dodgson* 1993; *Cohen/Sproull* 1995.

5 Combining knowledge of a codified type, but also using tacit knowledge will yield concatenated knowledge which is typical for scientific instrumentation and technical engineering. This type of knowledge is produced within a context of application (transdisciplinary knowledge). This type of research is of a more applied type and can build bridges between basic and applied research (*Jansen* 1995a, *de Solla Price* 1984). It is typical for the so called mode 2 of knowledge production (*Gibbons* et al. 1995).

risk, that educated employees who know explicitly instead of implicitly about the technology of the firm, will leave. This will not only mean a loss in investment into human capital, but also knowledge leakage. Kogut and Zander (1992) identify a paradox of replication. "Whereas the advantage of reducing costs of intra- or inter-firm technology transfer encourages codification of knowledge, such codification runs the risk of encouraging imitation." (390).

On the other hand, the fact that a lot of knowledge necessarily remains tacit and embedded into social routines of communication and collaboration, will always make it difficult to take away the knowledge of an organization.[6] Knowledge is a largely intangible asset. The capacity of a firm to use its knowledge and to combine and process different knowledge pieces thus is a core competence that is not only difficult to measure precisely, but also to imitate (Winter 1987; Hamel/Heene 1994; Henderson/Cockburn 1994; Zander/Kogut 1995; Venzin et al. 1998; Barney 1991).

Besides types of knowledge we have to distinguish between knowledge and knowing (Cook and Brown 1999). Knowledge is something you possess. Knowing is something you do, using knowledge of the several types. You possess the tacit skill of riding a bike and/or the explicit knowledge of how to stay upright, even if you are not riding at the moment. Using knowledge in many cases means adapting knowledge, creating new knowledge, i.e. learning.[7]

This insight can be connected to the inflation of types of learning in the literature, like learning by doing, by using, by interacting, by imitating.[8] The general thrust of the argument is that application and transfer of either explicit or implicit knowledge means learning and innovation. Contexts are always different for instance when imple-

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6 See *Buskens/Yamaguchi* (1999: 303) on the longer diffusion times in transit models in comparison to contagion models. In transit models, a resource actually travels in a network (like a scientist with a particular tacit knowledge), while in contagion models, a resource is duplicated by any transfer staying with the transmitter and the receiver (like explicit knowledge). Also the effect of local density, i.e. social closure, on trapping information in a special corner of the network is more severe in the transit model.

7 *Thus, Cook* and *Brown* redefine the spiral of knowledge by insisting that knowledge is not converted, but new knowledge is created.

8 *Hippel* 1988; *Rosenberg* 1982; *Lundvall* 1988, 1992; *Johnson/Lundvall* 1991. *Dodgson* 1993.

menting a new machine to an existing production flow, when reengineering the product of a competitor or when using a new instrumentation in scientific research. And this is why new knowledge will be created.

Knowledge can be created by different types of search procedures. Following Argyris and Schön (1978), I distinguish between single and double loop learning. Single loop learning is adaptive learning, incremental change of routines and concepts. It very often yields tacit knowledge, localized and context dependent. Double loop learning extends not just to the action, but to the premises of action, to the concepts and routines themselves. Thus, it tends to create knowledge of a more explicit and spelled out type. These two types of learning are echoed by two types of innovation and two types of science. Incremental innovation follows an established path of a technological paradigm, a dominant design (Dosi 1988, Anderson/Tushman 1990). Radical innovation establishes a new technological paradigm. Normal science works on spelling out an established scientific paradigm. Revolutionary science means discarding the old paradigm, seeing things anew, change of gestalt (Kuhn 1962/1976). Single loop learning can be trapped in local maxima. Double loop learning devalues established capital of all sorts, it is creative destruction (Schumpeter 1934, first published 1911; 2000).

Finally, there is the form of deutero-learning, i.e. reflexive learning. It means to establish the capacity for creativity, innovation and change management, on a permanent base. It means to change concepts and identities and choose deliberately between them not only in a crisis but constantly. It means to put one's identities and core competencies to debate, to be willing to intentionally create a challenging and even destroying environment. Since even science is mostly normal evolutionary science, this is not easily done, neither for individuals nor for organizations. Of utmost importance for this capacity is the loosening of the boundaries of the organization by boundary spanners, personal and organizational networks.[9] These networks of an organization constitute social capital that can be converted into absorptive capacity, scientific discoveries, invention and innovation (Jansen 1996)[10].

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9 See *Jansen* (1997, 2000b) concerning the capacity of organizations to evaluate and choose between learning strategies and learning environments.

10 Innovation used to be defined as the first marketing of a new product or the first introduction of a new process. It is preceded by the stage of "invention",

3. Production of Knowledge by Organizations, Markets or Networks?

There are several arguments for expecting better performance in the production of new and yet uncertain knowledge from networks of organizations rather than from any single organization or from organizations in a market. Since Schumpeter, innovation is seen as something that happens at the margins, in connecting and combining as yet unconnected ideas, markets, designs, materials (Schumpeter 1934). Several organizational forms like the functionally differentiated firm, the divisional form, the matrix form or project groups derive their rationale from the idea that combinations of differences are productive. Even more productive should be the combination of organizations into networks.

Organizations themselves suffer from an in-built resistance to change (Jansen 2002b). From an economic perspective organizations are mechanisms to guard against opportunism via hierarchy as well as to exploit economies of scale by specialization (Williamson 1991, Chandler 1977). Organizations are well designed for the exploitation of existing knowledge and competencies, they are less well designed for the creation of new knowledge. From the perspective of sociological institutionalism, organizations are instruments for the reduction of uncertainty, they establish a routine life. They are governed not just by efficiency and effectiveness, but they have to sustain collective identities and legitimacy (March/Olson 1989; Powell/DiMaggio 1991). To be self-identical, variation and innovation within an organization are always constrained. Organizational ecology even posits that structural inertia of organizations will make any change impossible. Change and innovation according to this view can only come about by the death of old populations and the birth of new organizations/disciplines/industries (Hannan/Freeman 1984). If organizations change at all or new organizations come into existence this is seen as an effect of competition within markets (Hayek 1979: 94; Nelson 1987 and 1988 on markets and variety production).

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i.e. making a design for a product/process by applying several types of knowledge and followed by diffusion of the new product/process. Nowadays, these stages are no longer neatly differentiated. Many feedback loops have to be acknowledged (*Kline/Rosenberg* 1986, *Brooks* 1994, OECD Oslo Manual 1992, *Schumpeter* 1934).

But markets are poor coordinating instruments. They are constrained to a very slim set of guiding mechanisms (prices) and imply a very reduced picture of relations (arms-length and short term). The idea of the market puts much emphasis on selection by competition. The pre-selecting processes within organizations do not come into focus. Organizations could very well be better adapted if pre-selections were done by networks than by an organization on its own. Next, the process of intentional generation of variations and new ideas is not examined sufficiently. Markets alone are too weak a mechanism to assure the intrusion of innovation into organizations. Besides self-made learning under competitive pressure, there are several other mechanisms which are supported by networks: imitating or even collaborating with rivals, collaborating with customers and subcontractors, setting of standards in an industry group, birth of new businesses via joint ventures.

Networks of organizations can make use of the special qualities of organizations. These are specialization, economies of scale, focus on core competencies, establishment of a collective identity and reduction of uncertainty. Networks of organizations also can make use of the qualities of networks: variety, mix of collaboration and competition, loose coupling, differentiation and co-specialization within a structure. These advantages gave rise to a steep increase in corporate alliances and small business networks particularly in the area of R&D and joint ventures in new technologies since the 1980s (Jansen 1995b, Hagedoorn et al. 2000; Hagedoorn 2002, 2003, Todeva/Knoke 2002, Noteboom 2003). At the same time, interorganizational collaboration and networks became the buzz-words in universities and state financed research organizations (Etzkowitz/Leydesdorff 1997, 2000; Nowotny et al. 2001). Thus, it may well be worthwhile to take a deeper look at the relation between knowledge production and networks.

The main producers of new knowledge today are not individual researchers or entrepreneurial inventors but research groups collaborating within and across organizations. These groups are embedded in different types of organizations (academic, government, industry), disciplines and industry sectors. They interact with other organizations and groups from diverse settings like funding agencies, customers like the military or hospitals, or production engineers.

New knowledge and especially basic innovations and new paradigms emerge mostly at the margins of disciplines, organizations and sectors.[11] It is produced by combination and exchange. This is why embeddedness into a knowledge community via research contacts, the flow of information, knowledge pieces, materials, instrumentation and people in research collaboration can be treated as a kind of social capital.

I define those aspects of a network structure[12] that open or constrain opportunities of action for individual or corporate actors as social capital (Jansen 1996, 2000; Bourdieu 1983, Coleman 1988, 1990; Lin et al. 2001). Social capital can be converted into other forms of capital. It can help with market entry, inspire an idea for a new product or help in overcoming problems of collective action. But an overdose of embeddedness into so called strong ties can also hamper innovation and produce too much confidence into established routines and products (Burt 1999; Kern 1998; Glasmeier 1991; Werle 1990, Grabher 1990, Anderson/Tushman 1990, 2002a).

The benefits of social capital are information/knowledge, trust into and enforcement of norms, brokerage positions which yield structural autonomy and entrepreneurial profits, and finally social influence com-

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11 *Hippel* 1987, 1988; *Tushman/Nadler* 1986; *Blackler* et al. 1998; *Gibbons* et al. 1995; *Knorr* et al. 1980; *Lemaine* et al. 1976; *Mulkay* 1972; *Schumpeter* 1934, 1946; *Tushman/Anderson* 1986; *Henderson/Clark* 1990, *Henderson/Cockburn* 1994; *Nahapiet/Ghoshal* 1998; *Alchian/Demsetz* 1972 on co-specialised assets, *Crane* 1972 on invisible colleges.

12 Networks in a methodological sense consist of a set of nodes (actors, events, ideas) and the edges/relations that are defined on them (e.g. information flow, influence, membership). From a technical point of view, thus a market is a special kind of "network". Nevertheless, the term network denotes in the literature usually something different than a market. It starts from a different image of man as embedded into social structure and thereby less undersocialized than homo oeconomicus and it ends in a critique of equilibrium theory which assumes that prices are all you need to know and that transactions with any market partner are a viable option for everybody without constraints in time, place, matching opportunities etc. (*Baker* 1984, *Granovetter* 1985, *White* 1988, *Podolny* 2001). Thus, part of the arguments of the new institutional economics and their analysis of networks as hybrid governance structures (*Williamson* 1991) are matched by sociological network theory (for the differences see *Jansen* 2002a, 1996). At the same time, social network analysis as an analytical tool is able to tackle all sorts of structures. Thus you need not presuppose that a structure is hierarchical (organizational structure) or atomistic (pure market). In the analysis this can be dealt with as an empirical question.

ing from legitimacy and reputation attributed by other relevant actors. The benefits accrue to individual and corporate actors, to groups of actors within a social structure, for instance to an industry sector, or to the whole network.

Different benefits from social capital are based on different social ties and structural configurations. Structures and positions that are beneficial in one regard for instance entrepreneurial profits, can be detrimental for other goals for instance sustaining social influence. The level of analysis is also important. Structures and positions that yield high benefits to one actor may be to the disadvantage for a group or for the network as a whole. And benefits to an actor may depend on his personal network, his position in a group within the network or on properties of the network as a whole. Thus social capital partly reveals private good features, but also features of a collective good. This also comes to the fore when you try to invest into your social capital. You never fully own your social capital because it depends on relations and indirect relations to other actors who have a say in this.

Concerning the structural base of social capital the main differentiation is between so called strong and trusted ties in densely knit networks and so called weak ties in sparse extended networks. The latter yield information and structural autonomy for brokers. These brokers can bridge so called structural holes and thereby combine diverse information/knowledge, transfer knowledge or extract arbitrages from their unconnected partners. Dense networks in contrast promote collaboration, the exchange and production of tacit knowledge, trust and shared norms, collective action of all sort.

Tie strength and network structure need not go together. Thus bridging relations need not be weak, and cliquish relations between a group of actors need not be strong. In the tradition of Simmel's formal sociology, Burt (1992) in his theory of structural holes claims that the structural pattern is most important. Thus he expects constraints for an actor from closed networks and entrepreneurial opportunities from a brokerage position where partners of ego are not linked with one another, regardless of tie strength.

Now, the central question is which type of tie and which type of network is more successful in innovation and knowledge production in the long run. What is the role of norm and trust breeding cliquish relations in knowledge production? Will they bring about stability at the cost of innovation and learning capacities? How important are weak ties? What is the role of unconstrained brokerage positions in the knowledge process? What is the effect of brokerage between cliques? Since network structures and ties that work in the exchange of codified and public knowledge may not work in the transfer and creation of implicit or proprietary knowledge, the ultimate question will probably be how to balance both types of ties and closed and open networks in an overall innovation network. And what does the acceleration of the knowledge process and intense feedback between basic research, technical application and markets mean for network structures?

4. Network Strategies, Competencies and the Governance of Networks

Evaluating the opportunities for knowledge production in networks we have to distinguish between two problems. The first one is a cognitive problem. How could the fundamental uncertainty in search processes be managed, given bounded rationality and local intelligence of humans (March/Simon 1958)? How could an intentionally rational search come to terms with the trade off between exploiting existing knowledge, competencies and machinery and exploring alternative opportunities? The second problem is a motivational one: how to construct a system of incentives and institutions that will guard against opportunistic behavior in networks? Which type of network structure, which positions in networks, which type of tie can successfully deal with these problems?

4.1 Stability and Dynamics of Knowledge and Competencies

The problem of how to manage the trade off between exploitation of existing knowledge and exploration of new knowledge boils down to whether to engage in local search or in long distance search. The typical routines of people and organizations are of course local search and incremental innovation processes (Nelson/Winter 1982, Simon 1991).

Evidence from complexity science and network analysis show that there is a relation between pre-existing network structure and size, and the returns to an innovative compared to a conservative local strategy. The general mechanism underlying this evidence is the effect of size, interdependency, differentiation and speed on volatility. The larger the markets/networks, the more structuration and differentiation evolves because of the bounded rationality of humans. There come into existence dense regions of cliques and structural holes between them. Trading within cliques reduces risk. But since large networks can't be fully connected, the gaps that inadvertently come into existence, produce volatility, for instance on financial markets (Baker 1984). Simulation studies show that in addition to network size, shorter transmission times and more differentiation in networks produce more volatility (Baker/Iyer 1992). This will devalue existing knowledge and competencies.

The stronger the interdependencies between agents in models of complex adaptive systems, the more it will pay to innovate (Levinthal/Warglien 1999: 347f). Introducing interdependence between agents striving for fitness means that clear fitness landscapes with a single peak turn into a rugged landscape with several peaks. In a single peak environment no matter what strategy agents opt for, incremental changes or wide ranging exploration, they will sooner or later reach the peak. By contrast, in a rugged landscape, a strategy of incremental change will trap them in local maxima. To reach a higher peak via short jumps, a valley of decreased fitness has to be overcome.

In real life, interdependencies between actors and organizations increase with the speeding up of communication and production processes. Globalization, the world wide web, improved information and communication technologies all strengthen interdependencies.

While necessary because of increased speed and interdependence, wide ranging changes (long jumps) are of course very dangerous. Most of them will mean a loss in fitness. It makes a good compromise between incremental and radical strategies of learning to put together expertise, ideas or artifacts that have proven to be instrumental in different contexts. Warglien and Levinthal (1999) use these insights for organizational design and point to new forms of innovation and product design as examples (see also Kline 1985; Wheelwright/Clark 1993; Blackler et al. 1998; Sutton/Hargadon 1996 on "wisdom" vs. creativity). Thus, to confine oneself to new combinations of "existing solutions" is probably a well adapted strategy in a rugged fitness landscape (i.e. a rapidly developing field of science and technology)[13]. This assures a balance between exploration and exploitation.

This balance used to be guaranteed by cognitive and normative standards of science and technology: by the guidance of academic research by scientific paradigms and by technological paradigms, learning curves and vested interests in production machinery and skills which guided technological innovation. A still more heterogeneous mix of viable partial solutions and the exploration of new combinations could be a promising route to new knowledge. Since adherence to a specific "solution" is tightly coupled to an organization, more variety and innovation can be expected from collaboration between different organizations than from collaboration within an organization. There is evidence that scientific performance of research groups is enhanced by organizational heterogeneity in their collaboration network and by the number of different disciplines in the research groups (Jansen 2000a). Innovativeness of patent outcome of a technological alliance is higher when partners come from different technology clusters (Stuart/Podolny 1999).[14] Thus collaboration with partners from outside the established technological or disciplinary position of an organization and across different institutional settings is a strategy to overcome the boundaries of local search routines within an organization.

On the other hand, dissimilarity and heterogeneity of organizations and ideas can very well be too large for successful collaboration and transfer. For the successful co-evolution of collaboration networks and semantic networks a balance between similarity guaranteeing understanding and dissimilarity to allow learning and innovation is necessary (Contractor/Grant 1996; Carley 1999). The business literature on strategic alliances, joint ventures and mergers is full of evidence on the advantage of common characteristics and mutual understanding for the successful implementation of an alliance and particularly for learning and innovation (Todeva/Knoke 2002: 363 ff.; Stuart 1998: 692 f.).

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13 See the idea of solutions looking for problems in *Cohen* et al. 1972 on the garbage can model of decision making which seems to me an inspiring organizational model for highly creative organizations.

14 Innovativeness of a patent is measured as non-overlap in patent citations with citers of previous patents of the firm. Technological clusters are established via patent citation analysis.

Transfer of knowledge and collaborative production of new knowledge and combinations depends on the absorptive capacity of an organization (Cohen/Levinthal 1990). This, to a large degree, is dependent on its own research and development activities. Only those who's work comes close to a specific scientific or technical idea or artifact can understand its usefulness and conditions. Especially for the transfer of tacit knowledge proximity and strong interaction are necessary. Thus actors need to exhibit a certain degree of similarity and nearness (Hansen 1999, Lundvall 1992).[15]

In an environment characterized by the globalization of knowledge and increased interdependence, organizational actors must do both – collaborate trustfully in strong tie structures that allow for the transfer of tacit knowledge and innovate by searching for structural holes and new combinations. Their type of interdependence changes from sequential or outcome interdependence to pooled or task interdependence. Sequential interdependence can be dealt with by arms length relations between organizations in an atomistic market. Pooled interdependence has been the realm of organizations, but will become the realm of networks. This requires that the second problem mentioned above, the establishment of a governance structure that prevents opportunistic behavior between network partners, can be dealt with satisfactorily.

The paradox of collaboration and innovation shows up in its motivational consequences. Dense and stable collaboration in cliques is a precondition for agency, for learning and innovation. But the incentives to break away from established collaborations and underlying norms and institutions increases with the taken for grantedness of these rules and institutions. The value of a collaborative position is devalued the more the number of collaborators increases. The potential value of a new brokerage position instead grows. And new brokers

15 Other mechanisms are of a more symbolic kind. Action and especially risk taking action and learning depend on making bridges between heterogeneous organizations and their "solutions". Successful innovation needs visions of new solutions and confidence into their viability. Representations of collective innovation goals and strategies thus can have a coordinating effect. It focuses the awareness of the collaborating partners and turns a mess of opportunities into clearer paths to follow up. Even wrong representations of opportunities can have positive consequences in that they help to overcome puzzledness and helplessness when confronted with a turbulent and overly complex environment (*Levinthal/Warglien* 1999, *Lundvall* 1992).

in turn will produce even more volatility and destroy old competencies and collaborations (Burt 1997, Beckert 1999).

4.2 Incentives and Institutions Governing Networks

Interorganizational networks show strong tendencies towards homophily and stability. In depth studies of collaboration patterns (Uzzi 1997) as well as longitudinal quantitative samples of alliance formation in several industries (Gulati 1995; Gulati/Gargiulo 1999, Keister 2001, Todeva/Knoke 2002) report that network formation is guided by prior experience with partners or partners of partners. The mechanism behind this strategy is reduction of uncertainty in the choice between potential partners. Complementarity of assets and trustworthiness are less in doubt for firms that are known from previous alliances. Trust is accumulated, collective norms and understanding grow so that the capacity of joint problem solving and returns from collaboration increase over time. Voice, e.g. overt dealing with mishaps and problems in the relation to a partner, is easier in networks than in markets.

Similarity of actors as well as personal familiarity are vehicles for the reduction of uncertainty. They breed trust, lower transaction costs and make coordination easier. Strong and embedded ties tend to go together with successful cooperation and high returns to an actor in the form of stability, profitability, successful innovations, access to tacit knowledge and to finance. There is ample evidence for the role of dense networks and strong ties as incorporating social capital for organizations.[16] But while strong ties are the ones with easy going relations, rich information and high yields, high performing organization

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16 See *Uzzi* (1996, 1997) on embedded strong ties in supplier-contractor-networks and their positive effect on stability and knowledge transfer; *Talmud/Mesch* (1997) on the positive effect of local cluster cohesion on stability of an industry (i.e. turnover in the top ten of the industry); *Ingram/Roberts* (2000) on the positive effect of cohesion and friendship between competitors on usage factor and profitability in the Sidney hotel industry. See *Uzzi* (1999) on better access to capital as well as lower interest rates for small and medium sized firms via strong ties and *Baker* (1990) on the prevalent strategy of embedding ties to banks; see *Hansen* (1999) on the benefits of strong ties for the transfer of complex and tacit knowledge and R&D project progress within an organization. Most of these studies analyze local networks around an focal actor (ego-network analysis).

also continue a set of weak ties in order to optimize access to information and bargaining power (Uzzi 1996, 1997, 1999; Baker 1990). Research collaboration via strong ties and the cultivation of information windows via extended weak ties are strategies of high performing organizations in order to enlarge their absorptive capacity (Jansen 1996, Hansen 1999). The search for complementarity reduces the effect of familiarity on tie formation. The probability of another tie increases with the number of previous ties, but this effect levels down and finally gets negative (Gulati 1995).

Studied trust and conditional cooperation (Sabel 1994, Ostrom 1990) in these early stages of the evolution of a network are based on direct relations, personal experience and the sanctioning capacity of oneself and ones direct ties. The structure is more or less governed by direct reciprocity. But over time, the reliance of actors on their previous relations for the choice of partners decreases. Third party relations and role relations and positions become more important for the choice of partners and for the confidence that opportunistic behavior will be effectively prevented or sanctioned (Lazega 2000, Buskens/Raub 2002). The network itself becomes an informational device for the choice of potential partners. Network position and prominence substitute in part for personal experience with partners (alike to the price mechanisms in markets, but with more information density).

This also means that network position becomes an asset of an organization. This social capital can be turned into several resources and particularly into intellectual capital, research opportunities and organizational autonomy. Network capital is more valuable the less marketable the products and performance of an organization, and the more complex, implicit and less visible its knowledge. Network position signals a history as a potentially interesting and trustworthy research partner. It attracts interesting partners and thus allows an organization to respond timely to newly emerging technological paths. Since global competition sets a premium on first movers, timely access and implementation of new technology through networks is important.[17]

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17 Although networks and positions in networks do become visible, the network of an organization is largely an intangible resource. It comprises formal and informal ties, indirect ties, network positions and characteristics of the whole network on the level of the organization as well as on the level of its members. It is difficult to describe, to imitate or to substitute and thus networking

Network positions have been measured in several ways. Centrality and prestige indices are important measures for the stratification of actors in networks.[18] Some indices of centrality (Betweenness, Bonacich power) bear a relation to the concept of structural holes which until now rarely has been measured directly. A strong effect of these measures on innovation performance would indicate that networks are governed by brokerage incentives. They could come from profits in the area of either creativity and information or in the area of extracting arbitrage from unconnected partners. Prestige indices on the other hand measure status hierarchies. A prestigious position gives esteem and influence to an actor. It derives from professional or hierarchical authority and legitimacy. A strong effect of prestige on innovation performance would indicate that networks are governed by some sort of institutionalized systemic trust and norms of fair collaborative behavior. Actors at the apex of this stratified structure might figure as some sort of generalized trustees that are honored for their professional authority. They guard by oversight, informal control and sanctions against opportunistic behavior in networks.

In the following paragraphs some evidences on whether it is the power and profit incentives or trust and legitimate norms of fair behavior that governs success in networks. A more macro-level approach to

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capacity becomes a strategic asset of an organization in global competition (*Galaskiewicz/Zaheer* 1999; *Nahapiet/Goshal* 1998; *Maskell* 2000).

18 Centrality of an actor is an aggregate measure of her embeddedness into symmetric ties. The most simple index counts the number of ties of an actor (degree or outdegree) in relation to possible ties. More sophisticated indices will also take into account indirect ties and weight them with their path distance. An open question is, how long a path may be in order to effectively transfer public or tacit knowledge, social influence or goods and services. The most sophisticated type of centrality index weights the impact of each actor who is connected to ego with her own centrality in the overall network (Bonacich-centrality).

Prestige of an actor is an aggregate index of her embeddedness into asymmetric ties. Prestige or prominence is based on the ties pointing to an actor. Centrality in asymmetric networks is defined on the basis of outward ties of an actor. The most simple prestige index is a count of the ties to an actor (indegree). There are also several ways to weight the impact of direct and indirect ties for the calculation of an actor's prestige (*Jansen* 2003a, Chapter 6 and 7). Prestige scores, and particularly their deviation from equivalent centrality scores, measure the influence and legitimacy of an actor (provided the relation is positive).

the question of network governance which deals with the roles and positions of the network as a whole is presented in the last chapter of this paper.

There is a lot of evidence on the positive effect of a central and/or prestigious position in a network on an actor's performance. But since many studies rely only on symmetric data, e.g. on alliance formation, a clear discrimination between the partly concurring hypotheses on power or influence governing networks is not possible. Powell et al. (1999, 1996, Powell 1996, Smith-Doerr et al. 1999) present evidence that centrality of a start-up in an alliance network has a positive effect on number of patents, non-operative income and research money, sales and number of employees. Patents attract minority investments and non-operative incomes, while a central position prevents a firm from being acquired.

Patents and patent citations (asymmetric data) become additional signals over and above position in a stratified network that attracts new partners. Patents thus are not just intellectual property rights. In high technology industries they are not so much used to keep rivals out of an area. Instead, they are the chips for bargaining over the terms in inter-organizational collaborative research. Also they signal the inclination of an organization to contribute to the knowledge pool (Jansen 1996, Smith-Doerr et al. 1999). Stuart (Stuart 1998, 1999; Podolny et al. 1996) reports a similar finding on factors influencing technological exchange alliances in the semiconductor industry. The higher an actor's prestige in the patent citation network, the more likely she was to become a partner in a technological alliance especially in the role of taking a license or otherwise receiving technology.[19] In the very strongly stratified semiconductor industry the license taking by a highly reputed actor legitimizes the technology of the partner. Since the effect on license giving is not significant, Stuart (1999) concludes that what is searched for is not in the first place knowledge and competence, but legitimacy.

For British research groups in an interdisciplinary emerging field, I demonstrated a strong correlation between the type and degree of embeddedness of a research group and its performance (Jansen

19 High prestige in patent citation networks had a positive influence on growth rates, too. This effect was larger for firms with a small technological overlap to its competitors than for those with a large overlap.

2000a). Centrality concepts that catch some of the ideas of structural holes are better able to explain the level of performance by the position in the research network, while for scientific contact networks prestige based indices (indegree centrality) do better.[20] Nevertheless indegree prestige was almost as good a predictor as betweenness-prestige in explaining performance.

Ahuja (2000) reports a positive effect of technological alliances on innovative success measured by number of patents in the world's chemical industry. The number of direct ties (degree centrality) and several measures of indirect ties had a positive influence on the subsequent patent output of a firm. The larger the number of direct ties, the smaller became the additional benefit of indirect ties and vice versa. Thus, Burt's (1992) argument on network efficiency is corroborated. Ahuja's study is one of the rare ones that tested the effect of structural holes on performance directly. His data showed that structural holes lower the innovative output of a firm. Innovation on the contrary seems to need embedded ties.[21]

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20 Betweenness-centrality in the research network has a larger effect on performance than in contact networks (beta = 0,86 vs. 0,51). Betweenness measures the bridging capacity of a actor between two not directly connected actors. Indegree prestige is the best predictor in the contact network (0,65) and only slightly worse than betweenness in the research network (0,73). The Bonacich power index which was constructed for negatively connected networks of competition for ties also shows a significantly higher effect on performance for the research network than for the contact network (0,70 vs. 0,56). Power of ego in this index is larger, the less the power of those who are the contacts of ego. Going one step further, ego's power is enhanced, if his contacts face other strong actors. The rationale behind negatively connected networks is that a resource can be given to just one actor, e.g. a confidential information, a job, a marital relation or a partner position in a research project. This produces competition for ties. See *Cook* et al. 1983, 1992, *Markovsky* et al. 1988, *Szmatka/Willer* 1995 for power in negatively connected networks.

21 Some evidence for a positive effect of structural holes comes from studies of managers' networks (*Burt* 1992, *Burt* et al. 2000, *Gargiulo/Benassi* 2000, *Podolny/Baron* 1997, *Gabbay/Zuckerman* 1998). May be, structural holes are more profitable for them than for organizations or groups. Collectivities are more dependent on the establishment of their collective identity, while identity for individuals seems to be given by their body and its clear boundaries. Thus, the need for a legitimate identity in organizations is better dealt with by a trust building strategy than by a brokerage strategy.

Summing up, the positive effect of both centrality and prestige on the innovative performance of an actor is strongly confirmed. A position that can reach all parts of a network via short paths or that can reach other actors with high centrality scores is instrumental for the knowledge generation process. Closed cliques where everybody can reach everybody else are not reported. Actors do differ in their centrality. But the relation between centrality measures and network cohesion on the one side, structural holes on the other side, is far from clear. Differences in actor centrality go together with brokerage positions in a network, but it is not necessarily the best broker position who gets the highest centrality score. Thus the impact of centrality scores on performance can only be taken as a hint that some structural holes which produce differentiation in centrality scores of actors, are beneficial for the brokers. What can't be concluded is that cliquish ties are absent in these cases nor that they have a negative impact.[22] On the contrary, the strong impact of indegree prestige (Jansen 2000a) and Powell's et al. (1999: footnote 7) finding that Bonacich-centrality for positively connected networks works better in their model than betweenness-centrality point to the importance of positively connected influence networks. They deliver legitimacy and support but not entrepreneurial opportunities for exploitation. This is also in line with Ahuja's data. There is another important finding: direct ties (degree/indegree scores) are much more important for performance than indirect ties measured in several ways (Ahuja 2000, Jansen 2000a). This is an indirect corroboration of the thesis that transfer, combination or production of knowledge needs direct interaction and probably also strong ties. The important role of direct interaction and some cluster stability for the transfer of knowledge and the co-operative network regime is also shown by simulation studies. Cohen et al. (2001) show that the establishment of a cooperative regime depends on structural and local characteristics in a network of adaptive agents. A stable role structure supports the building of reputation and increases the degree of cooperation significantly compared to a random network. Local stability in the sense of stable interactive pairs is almost as good in triggering collaboration as long as the percentage of

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22 An analysis at the level of whole industries showed that industry stability is positively related to the existence of structural holes and local cohesive cliques. But an increase in local densities lead to corporate instability (*Talmud/ Mesch* 1997). It increases competition, devalues existing collaborations and puts stronger incentives on the search for new opportunities.

new random partners stays below 30%. This can be taken as a hint on the relative balance that has to be maintained between a strong tie vs. weak tie strategy for building social capital. Another simulation study by Krackhardt (1997) deals explicitly with the relation between stability in groupings and the diffusion of an innovation. He comes up with the contraintuitive result that the mother site of an innovation has the best chance to spread it to surrounding groups when the exchange rate of group members between the sites is rather low, between 0,08 and 0,16. Lower rates end up in a split into concurring promoters and traditionalists, but higher rates end up in the extinction of the innovation. The reason is that the agents need some like minded partners in a group to stay with the innovation. To much turnover undermines this need of stability. Another contra-intuitive result is that the mother site does better when it is positioned at the end of the chain of five groups than in the middle. Again the mechanism behind this is the need for stability to harness the innovative idea.

5. A Macro-Level Perspective on Network Governance: Center and Periphery and the Sources of Innovation

As far as structural analysis of scientific and technological networks has gone by now, they all display a center-periphery structure. This means that the more central actors tend to interact strongly with one another while actors from the periphery direct more ties upward than towards their own group.[23] The most peripheral actor groups might even be unconnected in itself. As Schott (2001) in his analysis of the global knowledge networks notes, the attraction of the center produces even more inwardness of US science than could be expected from its performance. Thus, bandwagon effects of this sort and the scarcity of time and money for collaboration in effect prevent a network from becoming a totally connected clique and transform disparate horizontal structures into stratified ones. Homophily based on

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23 See the industry networks (automotive, industrial automation and new materials) studied by *Gulati* and *Gargiulo* (1999); *Stuart* (1999) on alliance formation in semiconductors across prestige differences in patent citation networks; for typical patterns found in science networks, see *Jansen* 1995c, *Shrum/Wuthnow* 1988; *Hargens* et al. 1980: *Mullins* et al. 1977.

personal relations is replaced by mobility aspirations based on status groups.

What can be concluded from this typical network structure for the question how a balance between sparse and wide ranging networks and dense cliquish structures can be maintained? The prevailing of this type of structure in science and technology networks shows that there coexist dense regions with strong stratification and differentiation. Dense relations connect actors who are structurally equivalent or connect peripheral positions to the center. What is missing are relations between the peripheral groups. This means that the center is in a position to exploit structural holes between the various peripheral groups of actors. Centrality and prestige, which were shown to be instrumental in knowledge access and production on the actor level, are highest for the actors in the center which enjoy a brokerage position.

But, this does not mean that dense relations and cliquishness are detrimental on the whole. After all, there are dense regions, even the center itself tends to be cliquish. The pre-conditions of learning and absorptive capacity and the overcoming of uncertainty suggest that cliquish relations are necessary for knowledge production. The argument in favor of a certain amount of cliquishness can also be strengthened by the evidences on the positive effect of strong ties, if they are accompanied by some weak tie relations.

For asymmetric network data the interpretation can go one step further. The role image then usually displays reciprocal relations between the center and its various periphery groups. The ties from the periphery which give the center its prestigious position are reciprocated by the center. This differentiates a center-periphery structure from a hierarchical structure. And it could denote a difference in the use of structural holes. Brokers can be more or less honest. Reciprocity in relations tends to go together with a sense of equity. From the point of view of the concept of Simmelian ties the idea of an unconstrained entrepreneurial center position is still more debatable. As Krackhardt (1999) posits Simmelian ties that embed one actor into two cliques are even more constraining for her than being embedded into one single clique. An actor in this position is under control of two potentially conflicting norm systems. This might catch her in a double bind. Concerning the typical center-periphery structure of knowledge production networks, it is the center actor who might well be the only common member of two cliques connecting actors from periphery 1 and from periphery 2. Center actors are highly visible, reputation effects are strong for them. By being a member of two or more cliques they are subjected to different normative and cognitive expectations from various peripheries, for instance different application perspectives and diverging standards of what makes a reputation or constitutes fair credit. If they nevertheless are the most innovative actors, this is more likely to be an effect of their capacity to integrate cliques, normative standards and information than of their capacity to exploit the partners. A conclusive test of this idea presupposes further analysis on the level of actors, not positions.[24]

Images structures can also be inspected for information about competitive pressures in the system. These pressures are largest between those actors who share the same position – because they are structurally equivalent. An obvious answer to this pressure is collaboration with one another. Density[25] within a technological niche leads to joint ventures in order to prevent duplication, to set standards, even for collusion. But it also devalues high status as a predictor of growth rates (Podolny et al. 1996).[26]

Concerning the question whether innovations come from the periphery, i.e. from low status actors or from the prestigious center actors, empirical evidence is inconclusive. In a study on investment banks and financing of new ventures, Podolny and Castellucci (1999) report

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24 In the British case study, already mentioned (*Jansen* 1995c, 2000a), a central position in the emerging center-periphery structure tended to support high quality research. High performing blocks in that structure were characterized by the combination of several disciplines in the research groups and by organizational heterogeneity in the composition of the positions. Their exposure to different norm systems via relations to different peripheries did not harm the scientific performance of the members of the center position. But it did harm their forcefulness in science policy terms. This has been explained by their lower internal centralization and larger heterogeneity (*Jansen* 1995c). Overlapping and contradictory Simmelian ties may a concurring explanation.

25 Density in the sense of niche theory is not the same as network density! Membership in the same technological niche is not derived from dense ties between actors but from the structural equivalence of actors, i.e. identical or similar relations to other actors, e.g. in a production chain.

26 See also *Burt* 1997 on the devaluation of structural hole bridging positions by the existence of competing bridges. *Ingram/Roberts* (2000) also report a strong tendency to choose competitors for collaboration in trying to manage hotel capacities.

that high status banks are subjected to less competitive pressures. They have a range of attractive opportunities and can choose low risk projects – without an innovative effect. And that is what they do. But semiconductor firms with high prestige were more likely than low prestige firms to evade technological niche density by forming alliances with partners from other technological areas (Stuart 1998). Innovations empirically spread sooner when they come from center positions with high legitimacy (Valente 1995, Strang/Soule 1998). Although they are less successful there is evidence that peripheral actors are more prone to innovation (Stevenson/Greenberg 2000)

To sum up, center actors enjoy a high reputation which makes them less susceptible to the temptation towards opportunistic exploitation of collaborating partners. High reputed actors have to loose much more when caught in cheating than low reputed actors. Their position yields high profits from the existing network and this explains their good performance. They have a vital role in guarding the cooperative regime of a network. Their surplus revenues from networks could be understood as some sort of balance for due behavior and sanctioning costs. While they are also in a good position for innovative strategies they may become self sufficient. Actors from the periphery instead are less visible and under lower pressure towards conformity to established norms and routines. They are therefore more susceptible to opportunistic strategies but often do not enjoy a productive network position. Relative encapsulation can be a fertile ground for innovation. But their structural position and the lack of legitimacy and reputation will be an obstacle for the diffusion process.

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