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Meeus, M.T.H.; Oerlemans, L.A.G.

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6. Innovation strategies, interactive learning and innovation networks

Marius Meeus and Leon Oerlemans

1 INNOVATION STRATEGIES OF FIRMS

1.1 Introduction

Technological competition and innovation confronts firms with the innovator's dilemma (Christensen 1997). Basically this dilemma is a variant of the flexibility-stability dilemma, which revolves around the question: how do firms reconcile the need for persistence in the pursuit of organizational goals and the need for change in the pursuit of organizational survival? How are environmental pressures translated into strategic action, and do institutional arrangements like networks play a role in this?

Innovation is a trade-off between competing risks; the risk of changing products, processes and routines threatening the reliability and accountability of organizations and the risk of organizational decline or even death due to a lack of change. Innovation processes in organizations appear to have both effects. On the one hand empirical research revealed that innovation enhances the growth and survival of firms. Innovation does contribute substantially to organizational survival by offering new growth opportunities (Brouwer and Kleinknecht 1994; Archibugi and Pianta 1996; Audretsch 1995; Lawless and Anderson 1996; Metcalfe, 1995). On the other hand innovation is a very complex and risky process, with low success rates and sometimes lethal effects. Innovations potentially disrupt and reform the organizational fabric, often in a fairly unpredictable and situation-specific way (Zammuto and O'Connor 1991; Dean and Snell 1991; Lundvall 1992; Leonard-Barton 1988; Dougherty and Hardy 1996). One study revealed lethal effects of innovation (Barnett and Carroll 1987; Barnett and Burgelman 1996). Due to its pro-innovation bias and its adaptationist perspective (Drazin and Schoonhoven 1996), much innovation research tends to stress that innovation benefits its producers and users, and simultaneously ignores the risks of the associated change processes (Abrahamson 1991; Freeman and Soete 1997; Leonard-Barton and Doyle 1996), or disregards its complexity. To the extent that risks

are associated with innovation, they are treated, as is the case for other decisions, as statistical uncertainties with a probability distribution known to all (Gopalakrishnan and Damanpour 1997). These theoretical and empirical flaws in innovation research hampered a full treatment of the innovator's dilemma and accordingly hinder the development of deeper insights into innovation strategies and how they are related to (institutional) environments.

1.2. Competing Perspectives on Innovation Strategies

The selection and adaptation perspective have distinct appraisals of firms' capabilities to align conflicting internal and external demands (Meeus and Oerlemans 2000). The selection perspective stresses environmental selection due to the limits of organizational influence over environments. The cognitive limits on strategic and efficient choice increase the risks and uncertainties associated with change, and consequently inert behaviour is considered as the best safeguard for survival (Stinchcombe 1965; Aldrich 1979; Hannan and Freeman 1984, 1989). The adaptation perspective stresses the co-evolution of organizational competences, behaviour and environmental dynamics and infers that a fit between strategic choice and environmental change significantly enlarges life chances of organizations (Nelson and Winter 1982; Haveman 1992; Tushman and Romanelli 1985; Langlois and Robertson 1995; Teece and Pisano 1998).

Hannan and Freeman (1984: 151) defined structural inertia in relative and dynamic terms. Structural inertia does not mean that organizational structures subject to strong inertial forces never change. It means that organizations respond relatively slowly to the occurrence of threats and opportunities in their environments. In particular, structures of organizations have high inertia when the speed of reorganization is much lower than the rate at which environmental conditions change. Inertia is caused by limited learning capabilities, which makes continuous fine-tuning of strategies and structures to changing environmental circumstances unrealistic (Hannan and Freeman 1984). Rational planning and controlled change is unfeasible because of the unpredictability of future environmental states, the political coalitions distorting rational organizational decision making and the loose coupling between intentions and outcomes, rendering every match between strategic action and environmental dynamics random. Since organizational change implies processes of dismantling one structure and building another, it makes organizations and their routines unstable, whereas inertia prevents organizations from the risk of lowering their performance in the short and medium term and from death in the long run. Due to the preference of market environments for consistent firm performance, inertia is the best behavioural alternative even in turbulent environments (Stinchcombe 1965; Hannan and

Freeman 1984, 1989). This yields the selection hypothesis: inertia prevents risky managerial conduct and improves performance because of high routinization and the avoidance of dismantling organizational structure and building another, and thus making organizational action unreliable. Therefore inert firms probably out-perform proactive firms.

Evolutionary economists (Nelson and Winter 1982; Langlois and Robertson 1995; Teece and Pisano 1998) certainly recognize inertial properties of organizations. Their account of inert behaviour builds on the notion of path dependence and routines, both limiting firms' learning capabilities. Nelson and Winter (1982) stressed that it is quite inappropriate to conceive of firm behaviour in terms of deliberate choice from a broad menu of alternatives that some external observer considers to be available for the organization. The menu is not broad, but narrow and idiosyncratic; it is built into the firm's routines, and most of the choosing is also constrained by the available resources and routines. Teece and Pisano claimed that a firm's previous investments and its repertoire of routines constrain its future behaviour, while opportunities for learning would be 'close in' to previous activities. They also stressed the risks of too much simultaneous change, because that might attenuate firms' competences to conduct meaningful natural quasi experiments (Teece and Pisano 1998: 203). Leonard-Barton (1996) succinctly summarized these ideas, noting that organizations' core capabilities can just as easily create 'core rigidities'.

The major cleavage between inertia theory and the evolutionary theory of the firm lies in the role of innovation strategies. From inertia theory one can infer that innovation is a major risk that firms ought to avoid, whereas Nelson and Winter (1982: 131) conceive innovative activities as a component of behavioural routines determining the competitive edge of firms. The benefits of inert behaviour are disputed by evolutionary economists because inertia implies the risks of not adapting. Inertia is deemed beneficial only in stable environments, while it is harmful in unstable environments. In unstable environments firm have to learn in order to survive. So if inertia hampers learning it is considered a risk (Langlois and Robertson 1995). Haveman (1994) contends that if the conditions that affect performance fluctuate greatly, then organizations that reproduce their previously effective structures will perform inconsistently. If the outputs required change frequently and by large amounts, the inputs available change in quantity, quality or relative proportions, or the applied technologies change, then organizations will be forced to alter their structures and activity patterns to achieve consistent performance. Haveman (1994) concludes that especially in unstable and uncertain environments, selection pressures will favour flexible organizational forms – forms that adjust to perform consistently. In their reflections on dynamic capabilities of firms Teece and Pisano (1998: 194, 201) also adhere

to an adaptation perspective. Winners in the global market places were able to demonstrate timely responsiveness and rapid and flexible product innovation, coupled with the management capability to effectively coordinate and redeploy internal and external competencies. So, in dynamic environments, narcissistic organizations are likely to be impaired. This yields the adaptation hypothesis: inertia inhibits learning processes and lowers performance because of growing deficiencies in competencies to align behaviour with environmental demands. Therefore proactive firms probably out-perform inert firms.

So far the environment-organization relation has been conceptualized in a unidirectional cause-effect direction in which the organization responds to environmental pressures. A third perspective on innovation strategies has an opposite take on the relation between regulation, environment and firm behaviour. This is especially relevant in the field of environmental regulation. This is legislation that establishes standards designed to control the material and energy outputs of society to the biophysical environment. It is argued that environmental regulation suppresses innovation due to the deterministic nature of environmental laws limiting firms' strategic choices, and constrains their ability to innovate (Breyer 1982). More specifically, critics argue that the bureaucracy required to comply with environmental regulation restricts firms from pursuing cutting-edge technology. Managers of environmentally regulated firms argue that it is harder to innovate because regulations often change unexpectedly, and because regulators are unpredictable. This increased uncertainty motivates firms to de-emphasize risky strategies such as innovation. The net effect of these constraints is reduced innovation, which many argue puts environmentally-regulated firms at a competitive disadvantage (Guttmann *et al.* 1992; Scherer and Ross 1990). For the Dutch population of innovator firms a negative effect has been reported of compliance to environmental regulation.

A competing argument is that environmental regulation, if viewed as an external jolt, can stimulate innovation within an organization (Marcus and Weber 1989; Meyer 1982). In the absence of external jolts, existing organizational practices are often not challenged, and members may resist innovation, fearing it will change the status quo (van de Ven 1986). A jolt such as environmental regulation may appear disruptive and threatening to a firm, but it may be necessary to induce innovation (Schon 1971). An example of the positive effect of environmental regulation on product innovation is found in chemical manufacturing. Faced with the rapidly approaching deadline for the worldwide phase-out of chlorofluorocarbons (CFCs), Imperial Chemical Industries (ICI), Du Pont, and Elf Atochem developed the technology required to produce CFC substitutes in record time. Development time was reduced from the industry norm of more than a decade to only five years (Weber 1993).

Summarizing, one can conclude that there are competing views on the link between environmental regulation and innovation (Porter and van der Linde 1995a, 1995b). Positive and negative effects are reported and empirically confirmed. Of course this overview is not exhaustive and probably applies to many divergent contexts, but to say the least, it gives clear indications that we need better specified theoretical models and data, allowing us to test these competing views as well as the factors mediating the effects of environmental regulation on environmental innovation.

1.3 Implementation Strategies

One of the challenges advanced by innovation theory and the knowledge-based theory of the firm is the relation between management and knowledgeable workers in cases of complex innovation projects. Increasingly, organizational analysts identify implementation failure, besides innovation failure, as the cause of many organizations' inability to achieve the intended benefits of the innovations they adopt. It applies to technology management in general, as a recent Delphi study revealed (Scott 1997). The issue of organizational learning about technology and the development of technology core competence turned out to have high priority among experts who had to identify the major unresolved management problems faced by companies. A broad range of innovations like quality circles, total quality management, statistical process control and computerized technologies often yield little or no benefits to adopting organizations, not because the innovations are ineffective, analysts suggest, but because their implementation is unsuccessful (Fleck 1984; Lyytinen and Hirschheim 1987; Majchrzac 1988; Cooper and Zmud 1990; Zammuto and O'Connor 1992; Hattrup and Kozłowski 1993; Klein and Ralls 1995; Klein and Sorra 1996).

The interdependence between management and knowledgeable workers is crucial in the implementation of complex innovation projects. Although interdependence mostly has a structural connotation, its effects on organization design also imply power relations and dynamics between organizational units and the actors involved. Especially in the behavioural theory of organizations, where coalitions are not supposed to have a generally shared, consistent set of goals, the management of interdependence between these coalitions is crucial (Cyert and March 1963).

In the adoption and implementation of major new technologies, and the related management of change, a higher order task interdependence of management and workers plays a key role, in which structural and cognitive aspects interact and impact on the effectiveness of implementation processes. First, by the fact that during change processes, impacting on organizational structures, the interdependence between management and workers is often

supported by worker or user participation. Second, because adaptive activities are often implemented in a short time span (Tyre and Orlikowski 1994) and impact heavily on the organizational microstructures. Third, this induces actors to monitor and judge each other's actions more intensively, which represents the cognitive aspect of interdependence. If workers do not use new technologies appropriately, corporate investments are detrimental for firm performance. Therefore the management of interdependence is considered as a key factor for the successful implementation of any innovation.

In our empirical research we found that the effects of user participation on implementation effectiveness in IT projects was strongly affected by cognitive aspects of interdependence. The more positive workers' judgments of managerial interventions, the higher the probability of positive effects of user participation on implementation outcomes (Meeus and Oerlemans 2002).

1.4 The Research Agenda

The outcomes of innovation strategies turn out to be very sensitive to contingencies at the level of the firm (size, age, absorptive capacities), and at the environmental level, for example, technological dynamics, market dynamics, internal organizational dynamics and regulatory dynamics (Meeus and Oerlemans 2000). There is hardly any empirical research that systematically integrates such contingencies. Therefore, we suggest a research agenda addressing contingencies moderating the relation between innovation strategies and innovative performance.

Furthermore, a systematic comparison of outcomes of innovation strategies, such as strategies drawing heavily on institutional resources, with or without network linkages, versus stand-alone strategies, would add considerably to insights into the antecedents of innovative performance, simultaneously integrating the institutional argument.

Given the costs of implementation failure, the need for user participation in complex process innovations and the changing role of worker councils (initially they decreased managerial autonomy, which in the Netherlands has been gradually regained by management through bypassing worker councils), and the growth of the number of more highly educated employees, we expect that the role of cognitive interdependence in implementation processes will probably grow.

Therefore, the management of innovation is becoming an even more complicated game than it was before. This complicated interaction of institutional, social, demographic and organizational processes in the production of acceptance of change is a research issue of considerable weight, all the more because the capacity to learn is constrained by acceptance and

thus the alignment of the motivational and learning process will be the hallmark of the most effective future organization (Jin and Stough 1998).

In general, innovation studies are rather apolitical and technocratic, and often oriented toward problems of efficiency. Often, this amounts to a disconnection between innovation studies and industrial relations. Certainly as to the management of innovation this needs to be amended. Industrial relations also impacts for the diffusion of innovation in societies. Our findings as to the efficacy of implementation strategies show that effective innovation implementation does not only enable diffusion of innovation but also facilitates efficacious innovation.

Finally, we suggest a research agenda dealing with the bi-directional relation between institutional dynamics and innovative activities of firms. Regulatory pressures and the associated institutional dynamics are mostly conceived as constraining innovation. Such a conception is at least short sighted because environmental regulation also creates niches for innovation opportunities, spurring interaction between dyads (users-suppliers), triads (buyers, producer and supplier) and sets of companies in regions with governmental agencies. This type of research is non-existent and is a very important challenge on the institutional agenda.

2 INTERACTIVE LEARNING AND INNOVATION

2.1 Introduction

In the literature on innovation systems there is a focus on learning and interactivity, which is still underanalysed. In this chapter a summary of this literature is given as far as it is relevant for innovation studies. In our view the notion of interactive learning is so important because it enables a theoretical link between the micro and meso/macro actor sets and the firm and hence can be conceived as a micro foundation of a larger institutional framework. In the institutional literature the notion of 'organizational fields' (DiMaggio and Powell 1983) made headway in defining a new agenda of sectoral analysis with an institutionalist flavour. A link between the analysis of organizational field(s) and the amount of interactive learning seems to be an interesting opportunity to develop an institutionalist contribution to learning within and between industrial populations.

2.2 Interactive Learning

Conceptions of organizational learning are omnipresent. Not only organizational theory has addressed the issue, but a range of other academic

disciplines (for example, industrial economics, strategic management and psychology) has also studied it. A number of reasons can be suggested why the study of organizational learning is so fashionable at present (Dodgson 1993). First, learning is seen as a key to competitiveness. Learning enables organizations to develop structures and systems that are more adaptable and responsive to change. Second, and partly related, is the deep influence that rapid technological change has on organizations. There is an increasing need for firms to learn to do things in a new, and often drastically different way. Third, the concept of learning has a broad analytical value.

Both within and between disciplines there is rarely any agreement as to what learning is, and how it occurs. Various fields of literature tend to examine the outcomes of learning, rather than inquire as to what learning actually is and how these outcomes are achieved. Learning, in the sense it is used here, relates to firms, and comprises both processes and outcomes. In general terms (Huber 1991), someone or something learns if the range of its potential behaviours is changed through the processing of information. More specifically for organizations, it can be described (Dodgson 1996) as the ways firms build, supplement and organize knowledge and routines around their competences and within their cultures, and adapt and develop organizational efficiency by improving the use of these competences. Competences are the focused combination of resources within a firm, which define its business activities and comparative advantage. This definition of organizational learning contains a number of important assumptions (Dodgson 1993):

1. Learning has positive consequences even though the outcomes of learning may be negative. Here, it is important to note that firms learn by making mistakes and solving problems. Morgan (1997) also stresses the problem-solving capacity of learning organizations.
2. Although learning is based on individuals in the workforce of the firm, it is assumed that firms can learn.
3. Learning occurs throughout all the activities of the firm. It occurs at different speeds and levels. Encouraging and coordinating the variety of interactions in learning is a key organizational task.

A major mechanism indicating the level or intensity of learning in firms is their internal R&D efforts. They also learn, of course, from a wide range of other internal functions, particularly from marketing and manufacturing and from the interactions between these functions. Furthermore, learning has both an 'internal' and 'external' component. External links, with customers, suppliers and other sources of information and knowledge, are critical in assisting a firm's learning processes.

In the context of innovation, learning implies a process in which all kinds

of knowledge are (re-)combined to form something new. The interactivity of this learning applies to its dependency on the communication between people or organizations that possess different types of required knowledge. Basically Lundvall's (1992) account of interactive learning clarifies: 1) how technological and market dynamics pressurize firms to innovate their processes and products, and 2) how this innovation process impels firms to interact forward and backward in the production chain.

In Lundvall's theory innovation is conceptualized as an informational commodity (Cohendet *et al.* 1993), and innovation profits are interpreted in a Schumpeterian way as transitory. In this view the acquisition and protection of information is essential in order to innovate and profit from the innovation, which explains the emergence of linkages as well as the importance of control. Lundvall's starting point is that a broader range of technological opportunities and a higher changeability of user needs cause a higher rate of innovation. Since innovation is by definition the creation of qualitatively different, new things and new knowledge, the opportunities and threats of technological opportunities, as well as changing user needs, have to be evaluated in order to know whether they can be translated into new product or process features. Particularly when a firm intends to innovate its processes or products, this feasibility check demands close cooperation between users and producers, because users provide the required information for the producers. This has two related consequences: 1) a higher rate of innovation causes more intense patterns of interaction between users and producers, and 2) a higher level of innovation (incremental or radical) affects the complexity of the knowledge exchange.

It is radical innovations especially that erase existing communication codes between users and producers. New codes have to be developed on a trial and error basis, which requires intensive interactions between users and producers compared to incremental innovations. All these consequences are more easily assimilated with partners in the vicinity of the innovating firm.

There is a relatively long tradition of research on interactive learning within this dyad: users and producers. Many authors stress the importance of interaction between several collective actors for the process of innovation. Some of them restrict themselves to theoretical work (Lundvall 1992; Teubal 1976), others concentrate on empirical work (for example, Hippel 1985, 1988; Pavitt 1984). In 1971 the Science and Technology Policy Research Unit (SPRU) tested two hundred measures explaining the patterns of success of innovation projects in chemicals and instruments. The single measure that discriminated most clearly between success and failure was 'user needs understood' (Freeman and Soete 1997). Teubal *et al.* (1976) found the same 'market determinateness' in the Israeli medical electronics industry.

In the seminal work of Hippel (1985), empirical findings were presented

stressing the importance of external sources for innovation. Of a total of 44 innovation projects in scientific instruments 36 (81 per cent) were user-dominated. He found that it was the user who perceives that an advance in instrumentation is required; invents the instrument; builds a prototype; proves the prototype by applying it; and diffuses detailed information on the value of his invention. Only when all of the above has transpired does the instrument manufacturer enter the innovation process. Typically, the manufacturer's contribution is then to perform product engineering work on the user's device to improve its reliability, convenience of operation and so on; and manufacture, market and sell the innovative product. Interestingly, this user-dominated pattern appeared typical for innovations which were more 'basic', as well as for the minor and major improvement innovations. The user-dominated patterns described by Hippel also appeared to hold independent of the size – and thus, presumably, of the internal R&D potential – of the commercializing company. Finally, Hippel observed that the pattern of a user-dominated innovation process appears to be true for companies who are established manufacturers of a given product line – manufacturers who 'ought to know' about improvements needed in their present product line and be working on them – as well as for the manufacturers for whom a given innovation represents their first entry into a new product line.

Pavitt (1984) extended the 'customer active paradigm' to a broader actor set, inside and outside the firm. Compared to Hippel, Pavitt refined the ideas on linkages with customers to linkages within the firm, stressing the role of internal departments, and between firms stressing the role of suppliers, public R&D and so on. It is remarkable though, that Pavitt did not mention the purchase and sales department as sources of innovation, especially since they link the firm to their suppliers and customers. Pavitt (1984: 354) found that for supplier dominated sectors (such as agriculture, housing, private services, traditional manufacture) the sources of technology were suppliers, big users and research extension services. For the scale intensive sectors (for example, bulk materials, assembly) he found that the production engineering department and (in-house) suppliers as well as the R&D department sourced innovation processes. Innovation among the specialized suppliers (such as machinery and instruments) was supported by the design and development department, in-house customers and users. Innovations in the science-based industries (such as electronics, electrical, chemicals) originated in the R&D department, public science and production engineering and in-house suppliers.

The empirical research of Nelson (1982, 1993) stressed the linkage between basic science and innovation. The strength of the linkage between firms and other technology-generating institutions in the US appeared to be strongly differentiated. From the questioning of research managers in 650 firms it was

found that all industries in the sample claimed a strong dependence on at least one field of basic or applied science, while a small number of industries – drugs, semiconductors, instruments – were very dependent on a single science. However this did not mean that they had strong links with university-located research. In fact, only nine industries claimed close links with academic science. Over 40 per cent of the firms questioned claimed that suppliers of capital equipment and components were important sources of innovation inputs. Johnson (1992) reports that the Nordic Innovation Survey shows that customers are an important source of product innovation ideas in Scandinavian firms. Universities and R&D institutions are also frequently mentioned.

This brief sketch of empirical work shows that researchers gradually broadened the external and internal actors relevant for the innovation process of the individual firm. All researchers mentioned customers. Johnson (1992) and Nelson (1982) both stressed the role of universities, basic science and R&D institutions. Pavitt (1984) distinguished interaction patterns within the firm (R&D department, production, engineering, in-house suppliers) and outside firm boundaries with customers, suppliers and government-financed institutes. However most authors did not provide explanations for the occurrence of interaction patterns.

2.3 A Research Agenda

Interaction and learning are critical constituents of the innovation process. Innovation requires the ability of a firm to recognize the value of new, external information, assimilate it, and translate it into the procurement and allocation of facilities, materials, components and knowledge. The interaction with its environment determines a firm's access to a diversity of resources, whereas the learning enables firms to transform these resources into innovations. Both interaction and learning contrast sharply with notions of lonely innovators with an invariable resource base and stress the dynamic features of innovating organizations.

This issue is even more pressing because, if given the option, most organizations would prefer to establish a minimum number of inter-organizational relationships inasmuch as these relations can constrain their subsequent action (Galaskiewicz 1985: 282; Hage and Alter 1997; Alter and Hage 1993). Given managers' preference for autonomy and maximum discretionary power one could call this an autonomy-dependency dilemma. Moreover, Lam (1997) argues that a large part of human knowledge is context bound, highly firm-specific and tacit in nature; and that there are limits to the extent to which knowledge can be effectively articulated, transferred and utilized. Reasoning from a behavioural and a knowledge-based perspective,

the triumvirate of innovation, interaction and learning is anything but automatic and raises the question, why networks and clusters are so important nowadays in the context of innovation.

We argue that it is particularly the complexity of innovative activities that impels firms to exploit external knowledge and build external relations despite the stickiness, firm specificity and social embeddedness of human knowledge, and despite the limited governance opportunities (Lam 1997). Following Alter and Hage (1993), Hage and Alter (1997), and Lundvall (1992), the complexity of innovative activities is by and large determined by the discontinuous nature of social, sectoral, technological and market developments (Tushman and Anderson 1986), to which firms try to respond, whether reactively or proactively. In such a context the preservation and structural alignment of an up to date internal knowledge base is virtually impossible, which in its turn explains the attractiveness of building external relationships. The organizational form of networks is considered as an effective organizational strategy because it enables firms to avoid risks and uncertainties (Håkansson 1987, 1989; DeBresson and Amesse 1991; DeBresson 1996) associated with innovative activities, either in the field of strategic positioning, or in the field of technical innovation. Simultaneously networking allows firms to exploit heterogeneous external knowledge bases, makes firms more aware of external capabilities and offers opportunities to adapt and learn and to develop new competences (Alter and Hage 1993; Cohen and Levinthal 1990; Lundvall 1992).

One research agenda covers the development of a theory augmenting the predominant resource-based view of learning, innovation, interaction and networks (Litwak and Hylton 1962; Cook 1977; Pfeffer and Salancik 1978; Cook and Emerson 1984; Håkansson 1987; Nielsen 1988; Hergert and Morris 1988; Tyler and Steensma 1995) as well as the knowledge-based theories on learning (Smith 1995; Jin and Stough 1998). In most economic research, networks are considered as an exogenous variable. Approaches which endogenise networks, like transaction cost economics, are seldom explored empirically. Furthermore, the proxies applied for the measurement of relationships or networks represent economic exchange more than networks. This is the case with the research on spillovers (Verspagen 1997a, 1997b; Harabi 1997) and input-output analysis (DeBresson 1996; Dalum 1992; Fagerberg 1992).

In contrast with the resource-based theory of networks and learning where firms' activities are taken for granted, we emphasize the complexity and structuring of innovative activities inducing the search and for utilization of external resources. Both the nature of innovative activities as well as the coherence of internal innovative activities determines the extent to which innovating firms have to draw upon external knowledge bases and hence

develop external relations. The complexity perspective implies on the one hand that growth of knowledge yields more elaborate production and innovation processes, whereas on the other hand the growth of the number of monitored external environments exponentially augments information flows. In tandem, this induces the rise of the awareness of both threats and opportunities. Inherent in complexity is the dilemma of coordination and cooperation, the need to build external linkages and control many discrete activities (Hage and Alter 1997). Furthermore, there is little comparative empirical work done on the interactive learning between innovating firms and distinct external actors like universities and research labs, and actors in the production chain (users, suppliers and competitors). There are very large differences with respect to the capabilities needed to cooperate with universities compared to cooperation with customers, suppliers or bridging institutions. Universities are difficult to access, whereas the others are not (Meeus *et al.* 2003).

3 NETWORKS AND INNOVATION

3.1 Introduction

In the preceding section we discussed the notion of interactive learning. This notion implicitly addresses the issue of networks and proximity. First the network literature will be reviewed and afterwards the spatial aspect of networks and innovation. We start with a review of studies of exogenous network research that focuses on performance effects of networks, more specifically the effects on innovative performance. Second we review research findings on distinct antecedents of networks. Next we summarize the main findings. Finally, we define a set of research agendas.

The network literature is very fragmented, so it is almost impossible to take stock of it. The main reason for this fragmentation is that network theory is considered as a 'handmaiden theory', since it is often used to support the elaboration of other theories but rarely becomes the focus of its own development (Galaskiewicz 1996). Among the long list of the many behavioural and social phenomena investigated relating to the principles and assumptions of network analysis are: community elite decision making, social influence, power and innovation diffusion, R&D and technological collaboration. There are several comprehensive reviews of the social network perspective available (Nohria 1992; Nohria and Eccles 1992; Wasserman and Galaskiewicz 1994; Wellman and Berkowitz 1988; Alter and Hage 1993; Oliver and Ebers 1998). A review of the economic network literature that deals with innovation is made by Meeus and Oerlemans (1993). In 2001 we

produced another paper reviewing the next vintage of network research related to innovation (Meeus and Oerlemans 2001).

3.2 Networks: Consequences and Causes

Do networks foster economic performance?

Stuart (2000) investigated the relationship between intercorporate technology alliances and firm performance in a large sample of semiconductor producers. He argues that alliances are both pathways for the exchange of resources and signals that convey social status and recognition (the status transfer argument). Stuart reports that the capabilities of alliance partners seriously impact on the performance (measured as sales growth) of the allies. Organizations with large and innovative alliance partners perform better than otherwise comparable firms that lack such partners. Consistent with the status-transfer argument, Stuart's findings also confirm that young and small firms benefit more from large and innovative strategic alliance partners than do old and large organizations.

Combs and Ketchen (1999: 884) report that firms low on resources successfully used inter-firm cooperation to surmount resource limitations, enabling them to perform quite well in terms of return on assets (ROA). Yet this relationship was heavily influenced by exchange conditions. If exchange conditions pointed toward full ownership, the use of inter-firm cooperation deteriorated performance severely. Mitchell and Singh (1996) showed that alliances raised organizational survival rates. Uzzi (1996) showed that apparel firms with strong ties to business groups enjoyed improved life chances. Powell (1996) and Powell *et al.* (1996) found that a sample of young biotech firms that formed many alliances experienced accelerated growth rates.

Do networks impact on innovation adoption/diffusion?

The seminal work of Coleman *et al.* (1957) starting in the fifties was the first to reveal an effect of social networks on the adoption of new drugs among a group of physicians. Coleman *et al.* compared the network impact with the impact of personal characteristics (professional orientation) on adoption rates of a new drug. Their tentative findings suggested that the network effect was the strongest. More integrated doctors introduced gammanym considerably earlier than socially isolated doctors (1957: 267). Yet Coleman and his collaborators also showed that the network effect is exhausted after a certain period of time and that there might have been successive stages in the diffusion of this innovation through the community of doctors. The first network to be operative as chains of influence appear to be those that connect the doctors in the professional relationships of advisers and discussion partners. Only then, it seems, does the friendship network become operative –

among those doctors who are influenced in their decisions more by colleagues they meet as friends than by those whom they look on as advisers or engage in discussion during their working hours. Finally, for those doctors who have not yet introduced the innovation by about six months after the drugs' release, these networks seem completely inoperative as chains of influence. The social structure seems to have exhausted its effect: those doctors who have not responded to its influence by this time are apparently unresponsive to it.

In the seventies and eighties Coleman's ideas were re-analysed, especially by Burt (1980, 1987). Burt's critique of Coleman set out to compare the mechanisms mediating between network structures or positions and diffusion. He claimed that the behaviour of network members was affected both by the cohesion of a network, and by the so-called structural equivalence between actors. Burt defined structural equivalence as two actors who have identical relations and hence jointly occupy a single position. In a topological sense these actors are structurally equivalent. This allows an alternative status-based explanation of network dynamics that complements the centre-periphery image in which the centrality of an actor is supposed to determine his actions. Status affects the evaluation of the intangible advantages of adoption by a potential adopter – that is, the structural equivalence of actors – in other ways than the adopters' social integration. The idea is that structurally equivalent actors act as a reference group and as such cause imitation of the behaviours of actors with the same status. The adoption of an innovation by a structurally equivalent network member signals the utility of an innovation. In his 1987 paper Burt – re-analysing Coleman's data – showed empirically that cohesion is much weaker in the aggregate than structural equivalence on innovation adoption (1987: 1326), which does not mean that cohesion has no effects on expert perceptions. Nevertheless Burt claimed that it is not cohesion but structural equivalence that creates the social pressure to adopt.

Johnson (1986) tested Burt's status effect in a community of fishermen along the North Carolina coast engaged in a process of innovation of their equipment, especially the nets. Did fishermen quickly adopt an innovation after structurally equivalent fishermen adopted it? His findings tentatively lend support to Burt's hypothesis. Yet he also doubts the effect. For instance, the kicker plate spread almost randomly among members jointly occupying positions. One specification added by Johnson is that since structural equivalence does not take into account the specific fishing activities, it is underspecified (1986: 354–5) and loses its explanatory value in the adoption of innovations.

Midgley *et al.* (1992) tested the relative effects of social cohesion versus structural equivalence in the setting of industrial diffusion processes. They find that network structures between adopters can have important effects on the diffusion process. Their simulation results suggest that social cohesion

impacts stronger early in the diffusion process, while structural equivalence is stronger after the first inflection point of the S-curve. Their survey results showed that both the structural equivalence and social cohesion effects were operative during the diffusion of fax machines and PC networks.

Do networks foster innovative performance?

Hagedoorn and Schakenraad (1994) demonstrated a positive effect of entry into technology alliances and innovation rates. Ahuja's (2000) longitudinal study of firms in the international chemical industry takes a structural point of view and reports that higher numbers of both direct and indirect ties have a positive impact on innovative output (patenting frequency). Yet the magnitude of benefits provided by indirect ties is significantly different from those provided by direct ties. Ahuja (2000: 453) reports that in fact the magnitude of benefits from indirect ties is relatively low. The point is that in many networks, indirect ties have two counteracting functions that potentially nullify the net effect for the focal actor. On the one hand, indirect ties are resources that extend the actor's reach in the network and improve his or her access to information. On the other hand, in many networks, such indirect ties are also competitors of the focal actor in terms of using such information.

Ahuja also analysed the interaction between direct and indirect ties. He found that the number of direct ties moderates the benefits of indirect ties. The embeddedness in a denser network with more direct and indirect ties is potentially beneficial under the assumption that the focal firm is able to absorb the resource flows. However, it turns out that the impact of indirect ties decreases if a firm has more direct ties. Because of the more limited addition to their knowledge base through their indirect ties and their more constrained ability to absorb and act on the information, actors with many direct ties may be unable to profit from their indirect ties, unlike actors with fewer direct ties. A third issue set out by Ahuja is which type of network structure is more beneficial: densely interconnected networks (cohesion theory) or structural-hole-rich networks (competition theory), or exclusive ties with a focal actor having few direct ties and one partner with many direct ties (exchange theory). The findings of Ahuja show that more structural holes in a firm's network, creating brokerage opportunities, impact negatively on innovative activity.

In our research we took an exchange point of view on networks and focused on the magnitude of effects of information exchange on the innovative performance of the focal firms. These effects were measured as information and knowledge transfer between actors engaged in an innovation network. In general we found that more frequent transfers with information brokers (trade organizations and consultancies), and so-called intermediary organizations (innovation centres and chambers of commerce) fostered innovative performance of firms. The magnitude of innovative ties with economic

exchange partners (buyers and suppliers) turned out to be the strongest (Oerlemans *et al.* 1998b: 305). However the impacts of networking proved to be highly contingent on sectoral technological dynamics.

In sum, as can be observed from the findings in the literature and our own findings, networks offer serious benefits for the improvement of economic performance, the adoption of innovation and the innovative performance. Obviously networks enable the solution of specific problems associated with innovation like sharing risks, reducing uncertainties, getting access to external knowledge or information, and other resource bases facilitating learning and innovation. Yet, these effects are left implicit in the aforementioned performance literature. If these factors are so important, they should also explain the emergence and formation of ties, as well as exchange processes enabled by ties between companies.

Causes of networking

The next question is: what are the antecedents of networking, and the exchange processes in networks? On the one hand there are many theoretical papers that give a broad description of the antecedents of networking. On the other hand, the empirical tests are restricted to some key factors. Unfortunately the hypothesized effects of these factors gained mixed empirical support.

In our research we explored some of the effects of exchange conditions on the likelihood of R&D collaboration as hypothesized by organizational economists (Oerlemans and Meeus 2001). Moderate uncertainty combined with high dependency and high frequency of knowledge transfer indeed yields the highest percentage of R&D cooperation between buyers and suppliers (Oerlemans and Meeus 2001: 84, 88). Results from descriptive analysis (cross tabulation) as well as a multivariate logistic regression turned out to be consistent. Gulati (1999) also reported that higher interdependence is associated with higher likelihood of alliance formation.

In a longitudinal study, Gulati and Gargiulo (1999) investigated the process of alliance formation in three industries (new materials, industrial automation and automotive products). They report the following results:

- Higher complementarity between members of a dyad gives a higher likelihood of entering an alliance (interdependence effect) (1999: 1472).
- The density of direct alliances in prior time periods has a positive effect on new alliance formation, which suggests possible legitimization effects (relational or repeated ties effect).
- Higher combined alliance-network centrality increases the probability of alliance formation (positional effect).
- More similar organizations are more likely to form a new alliance (a

similarity effect).

- If networks evolve towards a centre-periphery structure – that is to say it becomes more structurally differentiated – then the effect of exogenous interdependence is mitigated, and the network as such becomes a source of information for future partnerships (interaction effect between interdependence and structural differentiation) (1999: 1474).

In another study Gulati (1999) alters his take on the alliance formation issue to a resource-based view. Network resources result from the informational advantages that firms obtain from their participation in inter-firm networks that channel valuable information. The membership of a network allows firms to develop capabilities through forming alliances. Gulati reports the following findings:

- Firms that are centrally located in the alliance network – which means that they are member of a larger number of cliques (clique overlap centrality) and need less steps to reach other actors in the network (closeness centrality) – are more likely to form new alliances.
- Past experience with alliances had a significant effect on the likelihood of entering new alliances, but this effect could not be found for other dimensions of the ‘alliance capabilities’ measure like the diversity of alliances and the time duration since the last alliance decision.
- A very interesting finding is that material resource attributes – like debt position, solvency and performance – had no significant effects on alliance formation.

In sum Gulati’s research reports positive effects of the social context of network members (density, network differentiation), similarity, complementarity, past experience and network resources on the proclivity to enter new alliances. However, fairly standard material resources indicating the competitiveness of the firm had few effects on alliance frequency. Also network capabilities based on the learning experience in the alliance turned out to have a positive effect on alliance frequency.

Gulati’s theoretical framework is dominated by a structural focus in which processual and exchange aspects, and also resource-based explanations are left implicit, or measured with proxies only. Learning and information exchange and knowledge transfer are omitted. In our research these were the key issues. We have focused more on the exchange and learning processes between innovator firms and their partners, and the distinct explanations advanced in the literature. We concentrate on a comparison of distinct dyads, broadly speaking the buyer-supplier dyad and the industry-university dyad (Meeus *et*

al. 2001a, 2003). We found that the resource stock of (innovator) firms has a U-inverted relation with interactive learning. This relation is highly contingent on the type of partner and size of the firm. The linear effects of absorptive capacity were only supported for the interactive learning of larger firms with universities, whereas the linear effect of resource deficits did not receive any support. Mowery *et al.* (1996) also report limited effects of absorptive capacity in the acquisition of capabilities through collaboration.

3.3 Discussion of Main Findings

Organizations build cooperative ties to access capabilities and resources that are essential to pursue their goals but that are either under the control of other organizations or not available in their own resource base for whatever reason. In both cases organizations have to search for partners that do control the complementary resources. This feature functions as a point of attraction in the partnering process and determines the potential reciprocity between partners. Collaboration is associated with uncertainties for the partners. Sources of uncertainty are manifold, but we restrict ourselves to two main sources in the context of network formation. First organizations have difficulty in obtaining information about the competencies and needs of a potential partner. Second is the paucity of information about the reliability of the potential partner. Both create a hurdle for any type of collaboration.

The information problem is solved in two ways: on the one hand by allying with firms with whom the focal firm has already had contacts for a long time, and on the other hand by choosing highly reputable partners. Safeguards that provide sanctions for unreliable behaviour anticipate the problem of opportunism. By means of collaboration, this interdependence and the associated uncertainties are managed. Several conditions have to be met though – one can think of similarity, power asymmetry, stability, the prior partnering experience, capabilities of partners, efficiency and legitimacy.

As to the performance effects of networking, one can say that there is ample support. Yet several findings of Ahuja (2000) really put things in perspective as to effects of network size and structural holes. His work revealed that the benefits of the number of (in-)direct ties cannot be understood in a simple linear manner: more ties is not better. Besides an informational advantage, a larger number of direct ties also imply that firms are confronted with their monitoring and utilization limitations, which bring back in the resource-based and dynamic capabilities argument. The number of structural holes in a network – which is supposed to improve the information brokerage position of the focal firm – turned out to be detrimental for innovative activities. This implies that the resource base of a firm has a dual effect. On the one hand a stronger resource base enables a firm to develop and maintain relations in

networks. On the other hand since resource quantities are by definition limited, it also limits the number of ties that can be utilized efficiently. The work of Coleman *et al.* (1957) also suggest that the network effect on innovation adoption is exhausted over time. The work of Burt (1980), Johnson (1986) and Midgley *et al.* (1992) shows that the membership of a network affects innovation adoption in distinct ways, by status effects, as well as cohesion. So this allows for a further specification of the network effect.

The findings with respect to the antecedents of networking revealed that resource-based explanations gave mixed results on alliance formation as well as on learning. On the one hand our findings suggest that the resource deficits as well as the absorptive capacity argument should be specified given specific firm features, the type of partners and the exchange conditions in innovation networks. On the other hand the functional form of the effect (monotonic or non-monotonic) suggests that there are specific limits to the resource effects on network formation and learning.

Combining theoretical arguments turns out to have substantial advantages, compared to a single theory approach. It allows a more comprehensive theoretical treatment of research issues. For example managers do not only try to minimize organization costs, they also try to develop and utilize the available resources in a satisfactory way. In this respect transaction cost theory and the resource-based theory of the firm define different motives for managerial behaviour, and are more complementary than competing perspectives. A further advantage is that empirical analyses of multiple theoretical models always yield results, be it with respect to one or the other theoretical framework in the research model, whereas researchers using single theoretical models run the risk of leaving a researcher empty handed. Besides that it allows researchers to develop contrasting hypotheses. For example, if you attack the inertia hypothesis of organizational ecologists, it is one contribution to show that activity measures have the opposite impacts on firm performance. But it is a quite different contribution to show that inertia measures are negatively associated with firm performance, and alertness measures have positive effects on firm performance.

3.4 A Research Agenda

What is ignored in general is that the complexity of activities performed by the focal firm determines its resource deficits and the search direction for complementary resources, as well as the uncertainties involved. Although our findings only tentatively support these effects we think that the analysis of the complexity effect is a very fruitful direction for future research. One can easily imagine how the complexity of a firm's innovative activities determines the search and partnering movement through a network. Such an approach could

also be used for a comparison of the movements (horizontal and vertical) of innovator firms and non-innovator firms through their networks and of the causes of such movements. In the innovation process firms confront themselves with numerous limitations. Innovation is a process in which uncertainties, information flows and interdependencies all rocket sky high. This implies that the actor sets organized with a focus on innovations must have specific features to enter or take part in innovation races. They must be less risk averse, more flexible and less sensitive to the effects of change on routines. Formal arrangements have fewer grips on the exchange processes in innovation networks, and search processes are core activities there. Since resource and control problems are in general more explicit if a focal firm undertakes innovation projects, one would expect that the search for partners would be a process that could be guided by the description of the resource deficits. The issue of network size (Ahuja 2000) is very important here, because it defines the set of potential partners. The smaller the set of potential partners, the larger the dependencies within this actor set. Here a link with population ecology might be interesting.

In general, the measurement of governance mechanisms, resources, interdependence, control over resources and complementarity is rather opaque. All the more because there is considerable overlap between these concepts, these imprecise measures cause many interpretation problems. The application of concepts denoting structural aspects of networks are often interpreted in terms of their processual or exchange implications (for example, centrality: informational advantage or cliquishness mean that a firm has network resources). Another example is environmental dependence, which encompasses two sets of considerations: resource procurement and uncertainty reduction (Galaskiewicz 1985). We have never seen both dimensions clearly operationalized in a precise way. Grandori (1997) distinguished three types of interdependence (pooled, sequential and intensified). We never saw these interdependencies measured clearly. The same goes for governance mechanisms. Too often they are implied and not operationalized (Jones *et al.* 1997).

Another research agenda, fitting the theme of learning and innovation, has to do with knowledge flows and learning in networks. In innovation studies there is a large research domain labelled as 'science and technology indicators'. The research in this field purports to be the clarification of international technological dynamics. In this research one finds an enormous number of references related to the aforementioned theoretical and empirical work dealing with knowledge resources, technological capabilities, technological networks, spillovers and so on. However, the indicators used seldom or never measure 'real networks'. For instance patent citations are considered as reflecting a network. But is that the case? The citation of patents

from different firms could as well be interaction-independent, and as such tell nothing about the 'real networks'. In this specific field the most important renewal that has to take place is that attention shifts from networks measured by proxy, to 'real networks'.

In our future research we would like to develop a clearer understanding of the empirical relations between the specific structural features of innovation networks and the processual aspects like learning, partner search and choice, and resource transfer. The old Arrow learning curve approach is unsatisfactory here, because that yields innovation output measures like decreasing costs per unit produced, but black boxes the learning process as such. We think that in general the learning perspective is an underanalysed theme in network research. The question is now how firms develop the capabilities and costly-to-copy resources to achieve better innovation opportunities. Who are their partners, are they local or non-local? Also a more systematic comparison between regions and industries would be worthwhile, since we have described in several papers findings that industry and regional differences have effects (Meeus *et al.* 2001b; Oerlemans *et al.* 2001).

Another relevant issue in the context of innovation studies is network dynamics and network inertia. Network inertia could be the shadow side of network membership. Learning and search processes are intensified in innovation networks as compared to business networks focused on routine economic exchange, or on market positioning, like many strategic alliances. An interesting issue could be partner choice: which subset of the existing business partners is selected, or which new partners come to the fore. Selection of innovative partners outside and inside the business network probably differs in cases of disruptive technologies as compared to incremental innovations. Both actor sets populate the innovation networks of innovator firms, and they probably play different, sometimes even competing roles.

Finally the issue of the complementarity between networking strategies and organizational inertia is very relevant. Related to this is the issue of collective strategies. To what extent do network members develop collective strategies, and which types of interdependencies and activities make them do so?

4 SPATIAL ASPECTS OF INNOVATION NETWORKS AND INTERACTION OPPORTUNITIES

4.1 Introduction

Another take on competition, innovation and networks emerged in the realm of regional economics and economic geography. The literature on the relation

between proximity and technological change is reviewed. The general argument on the relation between location and agglomeration and knowledge transfer or spillovers is that context-specific, uncertain knowledge – what Hippel (1994) called ‘sticky knowledge’ – is best transmitted via face-to-face interaction and through frequent and repeated contact. Geographic proximity matters in transmitting knowledge, because it is inherently non-rival in nature, and knowledge developed for any particular application can easily spill over and have economic value in different applications. Therefore for any firm it is considered to be important to have knowledge-generating institutions in the vicinity. The proximity argument is reversed in the innovation strategies of multinationals.

4.2 Proximity and Technological Change

Malecki (1991: 72) states that ‘technology is one of the principal factors behind regional dynamics, but is dealt with least satisfactorily by either conventional or Marxist approaches’. In neo-classical models of regional economic development, technological development is introduced via a Cobb-Douglas production function, which looks upon capital as a flexible and manipulable production factor. Capital can appear in various forms and embody new technologies. Since labour and capital are substitutable, and productivity is measured in terms of output per unit of labour, labour saving investments are generally preferred when the aim is to increase the amount of output. This neo-classical model of regional development is both a growth theory and a theory of factor mobility because, if the assumption that production functions in all regions are identical is correct, labor will migrate from low-wage regions to high-wage regions. Conversely, capital will move in the opposite direction. Eventually, these regional economic growth processes will lead to converging per capita regional incomes. In this sense, neo-classical models of regional economic growth are in essence reallocation models, which consequently contribute little to an explanation of spatial economic inequality. Malecki’s judgment about the role of technology in neo-classical theory hits the bull’s eye (1991: 79): ‘And, significantly, technical progress is accorded surprisingly little recognition of its importance’.

The theories building on the concept of agglomeration economies can also be said to pay some attention to technological development. In a variant on Myrdal’s principle of cumulative causation, Siebert (1969) argues that a higher regional turnover leads to higher investments in R&D (‘demand pull’ hypothesis). The resulting innovation and knowledge yields a number of initial advantages for the region in question. In turn, these advantages lead to higher regional turnover and R&D. Although knowledge has a certain geographical mobility; it tends, in Siebert’s view, to polarize in certain locations in space.

This technological polarization goes hand in hand with a polarization of capital and labour resulting from the initial advantages of innovation mentioned before (higher profits and wages). These polarization effects are further reinforced if in a region economic advantages of scale present themselves, that is, internal advantages of scale and agglomeration economies. Siebert argues (1969: 40) that 'the more mobile capital and labor, the stronger are the polarizing effects which technical knowledge induces'. The result is that cumulative causation processes are reinforced by the spread of new technologies first introduced in big cities and regions. In other words, what this type of regional economic growth model addresses is the way in which the diffusion of innovations is associated with the size of a certain geographic area, often an urban area with its internal and external advantages of scale. These innovations are spreading in accordance with the urban hierarchy (the 'trickle down effect'). In order to emphasize the subordinate role of technology in this kind of approach, Malecki (1991: 87) sighs: 'Agglomeration economies, rather than technology, become the driving forces behind regional growth in these models'.

The relation between innovation and proximity 'revisited'

During the 1980s, the discussion in the spatial sciences about the relationship between innovation and proximity was strongly influenced by insights from other scientific disciplines, such as the theory of industrial organization and sociology. The introduction of the concept 'transaction costs' or the use of such concepts as governance structures, embeddedness, clusters and networks are cases in point. In addition, the relationship between innovation and spatial economic development is given a far more prominent place on the agenda. In this context, a number of theoretical perspectives, such as the theory of the 'new industrial spaces', the 'district' theory, the innovative milieu approach, and 'regional innovation systems' emerged (Oerlemans *et al.* 2000a, b).

If innovations are considered to be the result of cumulative learning processes (Lundvall 1992: 8), the performance of territorial innovation systems depends on the relations between diversity of sources of knowledge and proximity. To formulate it simply: 'A larger territorial space may contain more diversity, but this will not lead to innovation if there is not enough proximity to support communication' (Gregersen and Johnson 1997: 482). In this context, proximity does not merely involve physical distance measured in kilometres, but also in terms of time. However, other dimensions of proximity exist. Within this framework, Lundvall (1992) mentions economic, organizational and cultural proximity. The central idea is now that interactive learning and, as a consequence, innovation will be restrained if these distances become too great. Putting it differently, in this approach (geographical)

proximity facilitates the innovation process.

Lundvall (1992) contributed to the discussion on the relation between innovation and proximity. He specified the relationship between the nature of technological change and the importance of spatial interactions between users and producers. Three types of technical change are discerned, namely stationary technology, incremental innovation and radical innovation.

In the case of stationary technology, the technical opportunities as well as the needs of users are fairly constant. There are norms, standards and terminologies available giving a near complete description of the technology involved. In other words, knowledge is highly codified. Such a high degree of codification means that communication between users and producers can be performed over long distances. If this is the case, industries virtually become footloose with respect to technological innovation.

For incremental innovation, codes and channels of communication must be flexible in order to include technological opportunities and changing users' needs. Recurrent changes in product specifications, functions and qualities of artifacts constrain standardization. Consequently, codification of knowledge is more difficult. This means that messages are relatively complex and information cannot easily be translated. In this case proximity will play a role of importance. The proximity of advanced users plays an important role in the adaptation process of an artifact to local conditions. Such firms and industries, often a part of national industrial complexes or clusters, are not footloose. Comparative advantages are often based on spatial proximity.

In the case of radical innovation, codes developed to communicate a constant, or a gradually changing technology become inadequate. Producers who follow a given technological trajectory will have difficulties in evaluating the potentials of the new paradigm. Users will have difficulties in decoding the communications coming from producers, developing new products built according to the new paradigm. The lack of standard criteria for sorting out what is the best paradigm implies that 'subjective' elements in the user-producer relationships – like mutual trust and even personal friendship – will become important. These subjective elements are not easily shared across regional borders. So, here spatial proximity is extremely important for user-producer interaction in networks.

In sum, the more radical the process of technological innovation, the less codified knowledge is. The more tacit the knowledge communicated the more important spatial proximity between user and producer is. So, Lundvall assumes a positive relationship between the level of tacitness of knowledge and the importance of spatial proximity.

Although the innovation systems approach may initially seem applicable at various geographical levels, authors are divided on the question of whether the approach yields useful results at the level of (small) regional economies. This

is particularly owing to the importance attached to institutions in this approach. The argument is as follows. By definition, innovative activities almost always involve a considerable degree of uncertainty. Institutions, which incidentally are characterized by stability, are brought into action by actors to be able to operate and survive in this uncertain world. In this context, institutions are defined as 'the humanly devised constraints that structure human action. They are made up of formal constraints (e.g., rules, laws, constitutions), informal constraints (e.g. norms of behavior, conventions, and self-imposed codes of conduct)' (North 1994: 360).

The institutionalist issue at stake is whether these institutions operate on the local or the regional level. Gregersen and Johnson (1997: 483), for example, let the national level prevail over the regional or local level. They point out that institutional changes that are important for the process of technological innovation often involve governmental interference. This usually concerns, for example, intellectual property law, standards or contract law. In addition, an important part of the knowledge infrastructure is regulated and funded at the national level. Finally, they argue that the performance of innovation systems depends on effective communication and interaction between people possessing different knowledge and skills. This communication and interaction are more effective if they take place in a joint culture. In their opinion, this cultural homogeneity can be achieved to a considerable extent within a national state rather than at the regional level.

The proponents of 'regional innovation systems' contend that the region is a very relevant factor within the innovation systems approach. In this context, Lagendijk (1997: 18) quotes Howells, who argues that, where regional innovation systems are concerned, the way in which the national institutional environment (for instance, education and legislation) affects the local or regional level is of importance. This mainly depends on the so-called local institutional capacity. In Howells' view, the regional innovation system is the place for localized learning, unexpressed or implicit ('tacit') knowledge playing an important role.

At the other end of the continuum is the work of Barré (1996), who contends that for multinational enterprises (MNEs) space is a relatively less constraining entity for their innovation strategies than for small and medium sized firms (SMEs). MNEs have a bearing on the region, whereas SMEs are dependent on the regional facilities and have less location options. Barré (1996) contends that MNEs internationalize their innovation activities through the creation of international innovation networks (IINs) within MNEs, that is, the body of interactive innovation activities taking place between a firm (at home) and its subsidiaries abroad (in host countries).

Furthermore Barré distinguishes three strategies constituted by the formation of different types of networks:

1. Home-based R&D and local adaptation networks: the firm of origin centralizes most of the R&D, and the role of the subsidiaries abroad is limited to adapting the products to local markets. IINs are quite weak, and functional integration quite limited.
2. Networks based in the host country: R&D and innovation are centralized but not in the firm of origin: a subsidiary, because of its size and capabilities, takes responsibility for the innovation functions, for certain product lines or technological areas. IINs are quite important, and functional integration quite extensive.
3. Division of labour networks: the various capabilities that participate in the innovation process are located where they are at their best. The various sites are complementary and there is division of labour. IINs are important, and functional integration very extensive.

Subsequently Barré (1996: 204–18) explores to what extent the internationalization strategies interact with the countries' NSI. He takes the innovative capabilities of host and home countries as a starting point and makes predictions about the type of strategies evoked by them.

When the home country is both industrially and technologically strong, MNEs need not look abroad for technological capabilities and can limit themselves to strategy 1; when dealing with technologically strong but industrially weak countries, they will be interested in buying firms with good technological assets (strategy 2); MNEs in countries with strong technology and weak industry will behave similarly. Countries with weak technology (or a small NSI) will tend to develop strategies 2 and 3 towards strong technology countries, if they can afford to. Empirical analyses revealed that MNEs of the Netherlands, Switzerland and Sweden are inclined to strategies 1 and 2. The IINs are an extension of their NSIs, which are too small to support the needs of their big MNEs. Foreign MNEs have only small IINs in these countries.

4.3 A Research Agenda

Nowadays, local and regional governments in Europe and the US have become more active in technology policy than before the 1980s. This new regionalism can be seen as a response to a paradoxical consequence of globalization – the growing importance of the locality as a site for innovation. To preserve the competitiveness of regions there has been a proliferation of programmes intended to attract high-tech firms from outside the region with science parks, to stimulate start-ups in newly emerging industries by means of incubator labs, or to facilitate the transfer of knowledge to regional firms (Tödtling 1994). For this reason regional technology policy and regional innovation systems became an important issue.

Following policy makers, many researchers consider the interaction between regional actors as decisive for a dynamic regional development. The stock of production factors and the economic and technology policy initiatives are supposed to facilitate this interaction (Maillat 1991; Cooke *et al.* 1997; Nelson 1993; Bergman *et al.* 1991; Tödtling 1994). Interactions between regional actors indicate that firms and institutional actors utilize their regional resources and policies. This interaction indeed contributes to firms' innovative performance (Håkansson 1989; Oerlemans *et al.* 1998a).

The basic idea behind regional innovation systems is that proximity makes specific resources more readily available on the one hand. On the other hand, compared to relationships of a larger spatial scale, local relationships between firms and institutional actors (local universities and research laboratories) facilitate the utilization of resources because of cultural homogeneity (Lundvall 1992; Morgan 1997).

This alternative account of regional economic performance made relationships and networks an important variable on the research agendas of organization theory, (institutional) economics, and systems of innovation. However this has raised a number of problems. The literature on innovation systems lacks theoretical rigour or applies a naïve unidirectional approach in which institutional differences explain differences in innovative behaviour and performance (Nelson 1993). More refined accounts in which innovating firms draw on their institutional environments have never been tested thoroughly, like Lundvall's theory of interactive learning (Lundvall 1992). Studies of dynamic regions with intensive networking tend to be rather 'euphoric' and descriptive (Illeris and Jakobsen 1990; Tödtling 1994: 327). In most organizational literature on networks the regional dimension is not a relevant variable, while there is a tendency to treat innovation networks and strategic alliances as equivalents. The fad of network research yielded an enormous stock of literature, which is very fragmented and also rather uncritical. This partially explains the strong bias toward descriptive accounts of strong linkages and the benefits of local cooperation, whereas the under-utilization of local resources, the drawbacks of networks and weak ties are generally neglected.

Empirical research in one specific Dutch region (high-tech, largely SMEs, export oriented) revealed on one hand that impacts of proximity on innovation are weak, although for the larger part, the innovative partnerships with suppliers and buyers are regional. On the other hand our findings as to the relation between the knowledge intensity of innovative relations and their spatial distribution revealed that there is no relation between the extent of knowledge transfer and the proximity of buyers and suppliers important for innovation. We found some differences between incremental and radical process or product innovators regarding the spatial distributions of their

buyers and suppliers important for innovation, but the overall picture does not lead to a confirmation of Lundvall's (1992) and Maillat's (1991) ideas about the relation between the character of technical change and the interactions in space. The expected importance of proximity for firms with radical innovations in particular is only weakly supported by our data (Oerlemans *et al.* 2001). Despite the limitations, these empirical findings challenge an important theoretical issue in the regional innovation systems literature.

We also found under-utilization of resources provided by institutional actors – the bridging institutions as well as the public knowledge infrastructure (Meeus *et al.* 2000). These findings also imply important challenges to theorists on regional innovation systems. One important issue on the institutional research agenda could be the problem of utilization barriers to resources provided by institutional actors. Our findings suggest that several barriers have to be removed before innovating firms draw on their external environment. This raises the issue as to what kinds of factors explain the existence of utilization barriers. The explanations of this phenomenon are manifold and depend on which actors' standpoint is taken. Obviously, the dependence on specific technological, organizational and economic knowledge does not necessarily generate strong links between firms and the broader knowledge infrastructure. From the perspective of firms this can be explained with the possibilities they have for the acquisition of knowledge resources, and in addition to the goals they pursue with their innovation. Firms can recruit personnel with the skills and qualifications necessary to innovate. If such personnel is not available, or the risks of hiring new personnel are too high, firms can develop alliances with competitors, buyers or suppliers, and acquire the knowledge resources in that way. Reasoning from the position of the universities, the problem is different in nature. The financial structure of universities and higher education in the Netherlands as well as in many other European countries is mainly designated toward the production of graduates and scientific output, while it does not reward cooperation with firms. In the case of the Innovation Centres, the causes for their low innovation inputs can be found in the scale of these centres. Dutch Innovation Centres (ICs) vary between ten and thirty employees, which puts them in the vulnerable – because difficult to evaluate on hard output – position of information brokers. Consequently the real innovative work is done by other organizations than the ICs, which explains at least partially their low visibility in our findings. Another reason for weak ties with external actors is that the innovation process in most firms, but particularly in small and medium sized firms is often discontinuous. After all, most industrial populations consist for the larger part of SMEs. Finally it cannot be ruled out that firms and the knowledge infrastructure are kept at a distance, because the rewards and rents of

cooperation are either unknown or too small, or because the firms lack the absorptive capacity to assimilate the available external knowledge.

For the other part of the industrial population – the multinational organizations – the research agenda is slightly different. MNEs choose locations for their important R&D and production facilities by comparing the factor endowments of the countries or regions they opt for. This type of research is a challenge for institutionalist research because particularly the institutional aspects of industrial relations, labour markets and appropriability regimes are important institutional endowments guiding locations decisions. On the one hand this type of research links in a nice way the macro-level with the micro-level – NSIs to innovation strategies. On the other hand it suggests the emergence of ‘new’ interorganizational forms of innovation management.

Yet, the reported research of Barré (1996) also has important deficiencies. First of all the NSIs that are investigated are completely black boxed. Second the measurement of IINs can be challenged on several grounds: 1) is the country of the patent inventor a valid proxy for technological innovation activity in that country; 2) to what extent are financial linkages adequate proxies for linkages among firms; and 3) are IINs networks or economic exchange relations? Third the link between strategies and their measurement is very weak.

The first and third points are very important from a theoretical point of view and yield a substantial institutional research issue. It would be an important contribution to specify types of innovation systems and innovation strategies and see whether the empirical relations between NSIs and innovation strategies still hold. Also the measurement of IINs should be further developed to allow for substantial evidence for the emergence of this ‘new’ interorganizational form. A last important research agenda pertains to the problem of how NSIs can be designed to support the innovation strategies of both SMEs and MNEs, as well as how to become attractive to the direct foreign investment of MNEs that build IINs which are beneficial via spillovers to the local industrial population. Depending on the strength of the national system of innovation, contrasting effects of IINs can appear (Barré 1996: 207):

1. If local industry is strong, there are chances that an IIN from abroad, in its direct and indirect effects, will generate a virtuous cycle of stimulation, competition and beneficial externalities, all resulting in increased attractiveness.
2. If local industry and technology are weak, a foreign-based IIN may well tap into unique local R&D resources, focus on problems of no relevance to the host economy, and outcompete local industry. The effects are those of a disguised ‘brain drain’. But foreign IIN generated by foreign direct investment, especially in the case of strategy 1 (local adaptation), can

generate beneficial spillovers, for example by upgrading the standards of local suppliers; countries like Korea in the 1970s, Taiwan and Singapore in the 1980s and China, Thailand and the Phillipines in the 1990s are following this route to upgrade their NSIs.

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