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An empirical specification of the relation between technological dynamics and interaction between multiple actors in a Dutch region

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Regional systems of innovation from within

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Abstract

The purpose of this paper is to develop the micro foundations of a theory of innovation systems by exploring patterns of interaction between innovating firms and a set of actors in a Dutch region. First, two largely detached literatures on the interactionist perspective on innovation are described. There is the theoretical literature of Lundvall, and the empirical literature of Von Hippel and Pavitt. Lundvall's theory stresses the importance of firms and structured interaction among firms for the innovation process. While the empirical literature stressed the importance of the users in the innovation process, as well as internal departments like R&D, sales and production, and finally basic science. Connecting both literatures produced an actor set involved in the innovation process which is much broader than Lundvall's, and Lundvall provides the hypotheses about the antecedents of interaction among the actors involved in the innovation process. Basically Lundvall argues that patterns of interaction are affected by the the nature of the innovation process. By means of separate indicators for the nature of the innovation process, and separate variables measuring patterns of interaction we reworked Lundvall's hypotheses. This allows us to explore the regional system of innovation of North-Brabant from within, answering the following research questions: To what extent do suppliers, customers, the knowledge infrastructure and intermediate organisations differ in their contribution to the innovation process of innovative firms ? To what extent are patterns of interaction affected by technological dynamics?

Our findings revealed that patterns of interaction are indeed contingent on the nature of the innovation process. The type of actors involved in innovation processes were found especially within the value chain – customers and suppliers – and besides that inside the firm mainly production, sales and R&D. Also we found that the intermediairy organisations like trade organisations, chambers of commerce and higher education are the weak ties in this specific system of innovation. Our findings enhance a further specification of the theorizing on the antecedents of a firm's innovative behaviour within systems of innovation.

Introduction

The subject matter of this paper are the micro-foundations of theories on systems of innovation. The innovating firm is considered as the focal actor interacting with an actor set containing a broad variety of players, e.g. buyers, suppliers, intermediate organisations, the knowledge infrastructure, local and national authorities, facilitating or contributing to their innovation process. The competences of this actor set defines a region's "organizing capacity" (Van Dijck, 1992), as well as its competitive capabilities (Porter, 1990). Nelson (1990) called this set of organisations and their activity the "capitalist engine", as it drives technological change. So these patterns of interaction from the perspective of the innovating firm and its actor set should especially be analysed in order to build the micro-foundations of theories about systems of innovations. There are several reasons that justify such an endeavour.

The first reason is that most research on National Systems of Innovation (NSI) are on a fairly high level of aggregation. The performance in particular is investigated at the level of sectors, and technologies over longer time periods (Porter, 1990; Freeman, 1987; Nelson, 1993), not the behaviour or performance of individual firms, or regions. Generally linkage between industries is analysed by means of input-output analysis (DeBresson, 1996: Dalum, 1992; Fagerberg, 1992) or spillovers (Verspagen, 1997a/b,1998; Harabi, 1997). In general these higher levels of analysis give a rather superficial impression about patterns of interaction at the firm level within systems of innovations. Even in the volumes on National Systems of Innovation edited by Lundvall, one of the promotors of the principle of interactive learning between firms, there is not even one article dealing with firm level data. Lower levels of analysis in the literature on systems of innovations are strongly oriented on innovative clusters, inspired by the Porterian strand of thought (Jacobs, Boekholt, Zegveld, 1990; DeBresson, 1996). Also there is a large number of case studies which illustrate the embeddedness of the process of technical change at the level of individual firms (e.g. Håkansson, 1987, 1989), which often have a descriptive, qualitative approach, but they seldom test or develop hypotheses.

A second reason to elaborate on the interactionist innovation perspective is the predominance of evolutionary theory in the economics and sociology of technology and innovation, which has caused an interest in long term processes of technological change at the cost of the analysis of micro firm behaviour. The evolutionists focus on uncertainty, bounded rationality and instability, further marginalised the theoretical relevance of the role of the firm. The firm became the new black box. Therefore the scope for actors in the technological development remained minimal in the work of evolutionary theorists (McKelvey, 1988; Freeman and Perez, 1988). Yet, Freeman and Perez (1988) stress that the diffusion of technologies through the economy is not spontaneous but driven by the action of firms, just as it is inside the firm where the decision is taken to innovate. For these reasons, some evolutionary theorists, recognizing firms as the principal actors in the innovation process (Winter, 1982; Lundvall, 1992/1993), demand a rethinking of the units of analysis when analysing systems of innovation.

A third reason for working on the micro foundation of a theory of innovation systems is that it allows for an integration of existing literatures which have remained largely detached.In other words the building blocks are available but they have not been walled up. Representing these building blocks, we have in mind the work of Lundvall (1992, 1993) and Teubal (1976) on the one hand, while on the other hand there is a rich empirical literature on patterns of interaction in the economics, sociology and history of technology (Von Hippel, 1976; Pavitt, 1984), and network research (Håkansson, 1987/1989, Meeus&Oerlemans, 1993, Oerlemans&Meeus&Boekema, 1998). For different reasons the theoretical ideas of Lundvall have not spread among the researchers carrying out the case studies and innovation surveys.

The fourth reason to work on the interactionist perspective of innovation is that most literature, including both Lundvall's theory of interactive learning and much empirical literature, focusses on dyadic relations: e.g. a firm with its competitors, a firm with universities, a firm with its customers. There are few empirical studies available which address regional patterns of interaction and linkage between a broad variety of actors (Håkansson, 1987/1989; van der Knaap&Toriker, 1991; Krolis&Kamann, 1991; Kamann&Strijker, 1990). As far as these kinds of studies are available they are neither theory driven, nor produce hypothesis. Most of these are descriptive studies based on qualitative data.. Although they give numerous important insights, they do not add to our theoretical stock of knowledge on micro foundations of innovation systems.

The aim of this paper is to close this empirical gap, and join the empirical and theoretical literature by applying its hypotheses at the micro level of interaction between firms and sixteen other actors in the regional system of innovation in one Dutch region. In this way a regional system of innovation can be viewed from within. An exploratory analysis is presented of interaction patterns between actors within firms, and actors in the external environment. In order to develop an appropriate theoretical framework and hypotheses several questions have to be answered:

1. what kind of actors are discerned in the interactionist innovation literature?
2. what kind of patterns of interaction were found?
3. what are the antecedents of these interaction patterns?

The paper contains the following sections. In the first section we will build a theoretical framework. We shall review some of the major empirical findings on the interaction between firms and then describe Lundvall's theory of interactive learning. We will go on to connect the empirical findings and Lundvall's ideas, and combine both in a research model and a set of hypotheses. In the next two sections our research design and research findings will be described. Our findings will be described in the results section. The results will be confronted with the theoretical framework we have built. Finally, we will summarise our main findings and derive some conclusions.

Theoretical framework: interactionist perspectives of the innovation process.

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 (e.g. Von Hippel, 1985; Pavitt, 1984)

Empirical findings on the interactionist perspective: the foundings of the "customer-active paradigm"

In 1971 SPRU tested two hundred measures explaining the patterns of success of innovation projects in chemicals and instruments. The single measure which discriminated most clearly between success and failure was 'user needs understood' (Freeman and Soete, 1997). Teubal (1976a) found the same 'market determinateness' in the Israeli medical electronics industry.

In the seminal paper of Von Hippel (1976) empirical findings were presented stressing the importance of external sources for innovation. Of a total of 44 innovation projects in scientific instruments 36 (81%) were user-dominated. He found that it was the user who:

* perceived that an advance in instrumentation is required;
* invents the instrument;
* builds a prototype;
* proves the prototype by applying it;
* 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, etc.
* 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 Von Hippel also appeared to hold independent of the size - and thus, presumably, of the internal R&D potential - of the commercializing company. Finally Von 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) developed the "customer active paradigm" to an interactionist perspective with a broader actor set, within the firm and external to it. Compared to Von Hippel, Pavitt refined the ideas on linkages between firms, as well as sources of technology. He contends that besides customers/users there are a number of other sources of technology as well. Inside firms there are R&D departments and production engineering departments. Outside the firm there are suppliers and users, and government financed research and advice. It is remarkable though, that Pavitt did not mention the purchase and sales department as sources of innovation, while they do link the firm to their suppliers and customers.

Pavitt (1984, 354) found that for supplier dominated sectors (agriculture, housing, private services, traditional manufacture) the sources of technology were suppliers, big users and research extension services. For the scale intensive sectors (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 specialised suppliers (machinery and instruments) was supported by the design and development department, in-house customers and users. Innovations in the science based industries (electronics/electrical, chemicals) originated in the R&D department, public science and production engineering and in-house suppliers.

The empirical research of Nelson (1982, 1985) 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 percent 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 gradually the actor set considered to be relevant for the innovation process of the individual firm was broadened gradually. Simultaneously the idea of the lonely innovator, of the heroic enterpreneur has been adjusted.

Lundvall: a general theory of innovation as an instance of interactive learning

In Lundvall's view, '…the national system of innovation is a social system. A central activity in the system of innovation is learning, and learning is a social activity which involves interaction between people.' (1992, 1). Lundvall perceives firms as knowledge-accumulating institutions. This is the 'raison d'être' of the firms. Because firms can more easily accumulate knowledge and utilise it than individuals can. Markets do not accumulate knowledge, they connect knowledgeable actors.

Lundvall's specification of innovative firm behaviour is developed by taking the specific characteristics of the innovation process as its starting point and confronting it with the routine economic exchange process of commodities. Building on the specific characteristics of the innovation process Lundvall developed a view on firm behaviour which deviates from the mainstream theory of the firm in industrial organisation. Lundvall's theorizing on innovation as an interactive process is a departure from neo-classical assumptions on the behaviour of firms. Innovation is by definition the creation of qualitatively different, new things and new knowledge. Therefore, agents involved in the creation and adoption of innovations cannot reasonably be assumed to know all the possible outcomes of their activities. This problem is aggravated by the fact that involved actors have different valuations, preferences and expectations of the outcomes of innovations during the development process (Dornblaser, Tse-Min Lin, Van de Ven, 1998). So the bounded rationality of actors, implies that agents behave differently and are not homogeneous with regard to their behavioural rules. Rational calculation and decision making is severely constrained by the fact that inputs needed for an innovation can be estimated up to a certain level, but outputs are difficult to forecast. Nobody knows beforehand how users respond, or how user needs change during the development process. Errors of estimation in relation to future markets can go in either direction and are often wild and inaccurate. For instance the future market for computers, for polyethylene and for synthetic rubber was grossly underestimated, while in the case of nuclear power it has been vastly overestimated (Freeman and Soete, 1997). This estimation problem with regard to the trade off between inputs and outputs makes innovation a complex process.

To be engaged in innovation demands other mind sets, and social norms than the routine economic exchange. In the knowledge-intensive economy, other behavioural norms than those of rational, profit maximizing, selfish economic actors, are required. Economic actors will be involved more or less permanently in processes of interactive learning, sometimes demanding cooperation and sometimes the collective creation of complex new knowledge. Lundvall contends that interactive learning is seriously undermined if parties act exclusively from the viewpoint of calculation and maximising profits. Interactive learning is based on discursive rationality more than on instrumental rationality and stresses sets of norms like idle curiosity instead of efficiency, mutual respect instead of disrespect, and trust instead of opportunism.

Another essential aspect of Lundvall theory on interactive learning is that innovation affects market forms. Lundvall's theory introduced the concept of 'organised markets' as a coordination mechanism emerging in the process of innovation. Markets which are characterised by on-going change in technical opportunities as well as user needs become more 'organised' due to requirements of the innovation process. The interaction of user and producers in the context of product innovations, is based on communication about technological opportunities and user needs. In order to exchange information more efficiently, a common code of communication is developed. To leave such a well-established relationship becomes increasingly costly, and involves a loss of information capital. Organisations constituting the organised markets exchange qualitative information, and cooperate on the basis of trust and economic power. In the process of innovation, these specific organisational features are amplified in such a way that users and producers develop durable and selective relationships which explain the *organisation* of such markets. Much of the discussion on the emergence of organised markets as an outcome of technological dynamics and associated levels of innovative activity revolves around the problem of internalisation and appropriability of knowledge. Innovations of all types demand knowledge transfer between suppliers of materials or components and the producer of the final product.Without information on user needs, the redesign of functions and qualities of any artefact is impossible. Cooperation in the definition stage, the development stage, or even introduction to user organisations is often used to appropriate that complex knowledgde of users.

In order to give a more systematic account of Lundvall's theory we have reduced it to some hypotheses. In Lundvall's theory innovation is conceptualised as an informational commodity (Cohendet, Héraud & Zuscovitch, 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. Next Lundvall specifies the kinds of information which govern the innovation process, from its onset untill ist conclusion. Both kinds of information determine the possibilities of firms to make rapid responses to market demands and technological opportunities. On the one hand the specific information about the nature of the technological dynamics , and the changeability of user needs are the exogenous forces driving the user-producer relations. Both the technological opportunities as well as user needs offer firms possibilities to innovate their product and/or processes. This produces the first hypothesis.

1. *The higher the level of technological opportunities and the higher the changeability of user needs the higher the rate of innovation.*

However both kinds of information need a feasibility check : can technological opportunities be translated into new product/process features?, and to what extent can user needs be translated in technological features of existing artefacts, or into new artefacts? This feasibility check demands close cooperation between users and producers only if the firm is willing and planning to innovate. This allows for two hypotheses:

2. *The higher the rate of innovation the more intense the patterns of interaction between user and producers.*

The second hypothesis can be specified by the type of innovation (process/product), and the level of innovation (incremental/radical), because both affect the complexity of the knowledge exchange. Cooperation and exchange of qualitative information between users and producers within firms is less difficult than between users and producers separated by a market. Because process innovations often take place within firms, the exchange of qualitative information will be realized by means of a number of existing codes and channels of information. Where the users are outside the firm (product innovations) such codes and channels of information have to be developed.

3. *The frequency of interaction and exchange of qualitative information is lower for process innovations than for product innovations.*

It is especially radical innovations that erase existing communication codes between user and producers. New codes have to be developed on a trial and error basis, which demands from both users and producers a temporal dimming of their expectations during the search process.

4. *Radical innovations amplify interactions between users and producers more than incremental innovations, and therefore accelerate the transition from pure market to organised markets, and simultaneously strengthen interaction.*

A confrontation of the empirical literature and Lundvall's theory on the customer-active paradigm

The empirical and theoretical literature - although often citing each other - are detached on some important points. Lundvall restricts his theory to user-producer dyads, while the empirical literature comes up with a broad variety of actors interacting in the innovation process. Lundvall's ideas on the sources of linkage between actors (technological dynamics), are often quoted though never investigated in the empirical literature. In that sense Lundvall's theory is a focussing device which doesn't focus research so much as sensitized researchers. The last point we want to stress is that both the literatures largerly neglect the theoretical accounts for the strength of linkage between actors.

Accordingly, there are two aspects of the interactionist perspective on innovation to be elaborated: first, there is the specification of actors involved in the interaction, second there is the explanation for the strength of relations.

Lundvall seems to define relevant actors within the value chain. However suppliers are left out, while Pavitt (1984), and Von Hippel (1976), stressed the role of suppliers. Although there is evidence that innovating firms cooperate with the knowledge infrastructure (Höglund & Person, 1987; Van Dierdonck, 1990; Mitchell, 1991), universities as well as higher professional education are absent in Lundvall's article on interactive learning. This also applies to linkage amongst competitors (Von Hippel, 1987; Grabher, 1991; Kleinknecht & Reijnen, Hagendoorn & Schakenraad). Where Lundvall achieved some specifications in his theory of interactive learning, his theory deals rather superficially with the kind of actors involved in innovation processes. He distinguished user and producers but gave no further refinement. Organisational structures of producers, types of users, the influence of suppliers, other sources of new technology, institutions and organisations engaged in the process of technical change like universities, intermediaries and the government are largely ignored.

Second, there is the issue of the strength of linkages which is neither explicated in the empirical literature, nor by Lundvall . In Lundvall's view every producer ought to have strong relations with each user, which is obviously not the case according to Pavitt's findings. In Lundvall's theory several mechanisms account for the formation and longevity of user-producer interaction. But one mechanism is essential, it is the complexity of the knowledge required for effective interaction. As complexity rises, cooperation intensifies. Besides the

technological dynamics, and the changeability of user needs, both initiating innovation processes, the antidote to neoclassical fallacy of opportunism - trust - is the main theoretical mechanism explaining network relations in the innovation process. But trust explains primarily the longevity of relations, not the strength or weakness of interorganisational relations. Finally one could notice that if knowledge flows become more complex, then actors - especially users –hesitate to continue such a relation without any prospect of the outcomes. Also the partner choice can be discussed. Lundvall suggests that producers ought to cooperate with users, which is obvious, but when we look at Granovetter's ideas on the strength of weak ties and embeddedness (1973, 1985), other types of actors or especially **new users** would be interesting partners.

Toward a resarch model and hypotheses

Our research model aims at dealing with the deficiences of the interactionist innovation literature by means of: 1) specification of the actor set involved in the innovation process, in order to extend the actor set discerned in Lundvall's theoretical view, and 2) we will advance one straightfoward theoretical scheme from sociological network analysis which helps the interpretation of differentiation in the strength of interorganisational relations in the context of innovation processes.

The concept of actor set is based on Evan (1993). He takes as the unit of analysis a class of organisations and traces its interactions with various organisations in its environment, that is with elements of its "actor set". Evan furthermore distinguishes the "focal position", for the organisations taken as a point of reference. Within a regional system of innovation we take the individual firm as the focal firm, whose behaviour is analysed. The focal firm is supposed to interact with a complement of the actor set in its external environment, as well as in its internal environment. One of the useful schemes refining especially the producers' intraorganisational actors contributing to the innovation process can be found in Kline's chain-linked model of innovation (1990a, b). Kline's model recognizes that development, design and production engineering, the production process and customer feedback usually make the largest contribution to the innovation process. It thus incorporates information links and feedback loops between market findings, design, production, distribution and research. This model is valuable in providing a more realistic representation than Lundvall's abstract producer concept. In particular, it captures some of the rich diversity and iteration of interaction between groups and activities *within* the firm. Kline's model however, says little about knowledge and information flows between the firm and any external sources. Another extension of Lundvall's actor-set is to add suppliers. The user-producer dyad than becomes a tryad.

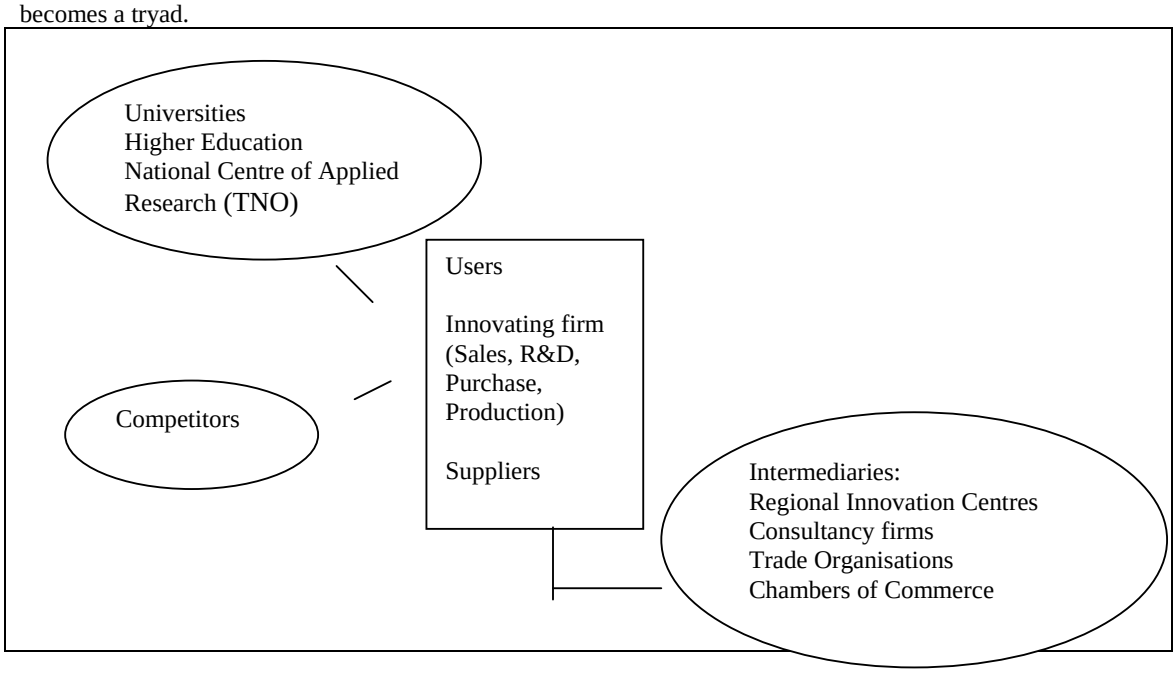

Figure 1 Actor sets within regional system of innovation

There is a growing literature on networks of innovation in which these external sources are taken into account (Schrader, 1991; Saxenian, 1991; Mitchel, 1991; Lawton Smith, Dickson & Loyd Smith, 1991; de Vet & Scott, 1992; Håkannson, 1987, 1989: Oerlemans, 1996; DeBresson & Amesse, 1991; Meeus & Oerlemans, 1993). Other frequently studied external corporate and governmental actors are eg.: universities, higher professional education, intermediairy organisations (eg. trade organisations, chambers of commerce),

competitors, users, suppliers etcetera. The public knowledge infrastructure has to be added because it provides the basic science as well as the labour supply necessary to carry out R&D (Pavitt, 1993). Finally there are a number of intermediairies – "bridging institutions" - sometimes public, sometimes private organisations, sometimes associations: e.g. innovation centres (financed by the national government), chambers of commerce (public), consultancy firms (private), finally branch or trade organisations (associations).
In this way one can view a regional system of innovation as the innovating firms surrounded by a number of actors who are all in one way or another linked to the innovation process of the focal firm and to each other.

The second addition is a theory explaining the strength of links between organisations involved in joint innovation processes. Interaction between collective actors, is defined as a situation where the behaviors of one actor are consciously reorganized by, and influence the behaviors of, another actor, and vice versa (Turner, 1988: 14). In theories on regional and national systems of innovation the concept of interaction is crucial, but seldom elaborated upon. We'll introduce one theoretical scheme here usefull for tapping the mechanisms underlying interactive learning[1]. In the so-called Emerson-Cook programme network analysis is underpinned with general exchange theory. In Emerson's scheme analyis begins with an existing exchange relation between at least two actors. This relationship has been formed from (1) perceived opportunities by at least one actor, (2) the initiation of behaviours, and (3) the consummation of a transaction between actors mutually reinforcing each other. [2]The theorems describe the dynamics of power as a function of one actor's dependency on another for valued resources, whereas balance is conceptualized as a process whereby dependency is reduced over time. In Emerson's view, a power advantage represents an imbalanced exchange relation. Balance is a situation in which B's dependency for resources from A is equal to dependency for resources from B. A basic proposition in Emerson's scheme is that, over time, imbalanced exchange relations tend toward balance, due to balancing operations. Emerson distinguished the following balancing operations:

- A decrease in the value for actor B of reinforcers, or rewards, from actor A.
- An increase in the value of reinforcers provided by B for A.
- A reduction in the alternative sources for the rewards provided by B for A.
- An increase in the number of alternative sources for the reinforcers, or rewards, provided to B by A.

The fluctuations in the value of rewards determines the strength of links, together with the number of sources available to obtain the resources. So when interorganisational linkages are weak this can imply that the valuation of the available rewards decreased or was lacking anyway, or that the stock of resources has decreased. The question raised by this theory is what rewards do actors engaged in an innovation process have in order to reinforce each others behaviours. Lundvall might answer: knowledge serving more efficient and efficacious product and processes, improving competitiveness of the private actors involved and legitimation for the public actors involved. [3]
With this model of the actor set and the theoretical underpinnings, Lundvall's hypotheses can be reconsidered.[4] Hypothesis 2 will be specified on the basis of our model of the focal firm and the actor set, and the added operationalisations of innovation rate: sectoral technological dynamics (Pavitt, 1984), and search types (Mezias&Lant, 1994; Nelson&Winter, 1982, Johnson, 1992, Lundvall, 1992). Hypothesis 3 and 4 will be elaborated by specifying the actor set. The independent variable - rate of innovation - is represented by five different indicators:

- Sectoral indicator of technology dynamics by means of Pavitt's sector classification. He distinguished four sectors. The *supplier dominated firms* can be found in traditional sectors of manufacturing, and in agriculture, housebuilding and many professional, financial and commercial services. They are generally small, and their in-house R&D and engineering capabilities are weak. Consequently supplier dominated firms make only a minor contribution to their process or product technology. The *scale intensive producers* are found in food products, metal manufacturing, shipbuilding, motorvehicles, and glass and cement. They produce a relatively high proportion of their own process technology, to which they devote a high proportion of their innovative resources. Innovating firms are relatively big and have a releatively high level of vertical technological diversification into equipment related to their own process technology. The *specialised suppliers* – mechanical and instrument engineering firms – produce a relatively high proportion of their own process technology too, but he main focus of their innovative activities is the production of product innovations for use in other sectors. Innovating firms are relatively small. The *science based industries* can be found in chemicals, oil, and electronics. These firms are relatively large, have a high R&D

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1 *Regrettably economic literature and sociological resp. social psychological literature are very remote from each other, implicating there is little theory integration in subjects where it would be worthwhile to develop more apprehensive theories of socio-economic phenomena such as networks, cooperation and linkage.*

2 *One can easily recognize the familiarity of this exchange theory with the ideas of Lundvall.*

3 *We don't want to reflect long on this further specification of the kind of rewards because this is not a part of our research question.*

4 *Hypothesis 1 is taken for granted in this paper and will not be tested here.*

intensity, which is done in-house, They produce a high proportion of their own process technology, as well as a high proportion of product innovations that are used in other sectors (Pavitt, 1984.

- Search types measured in terms of levels (high-low) of search activity. We distinguish: innovative and problemistic search. Problemistic search is derived from Cyert and March (1963: 120) and innovative search is derived from Mezias and Lant (1994). By problemistics search Cyert and March mean search that is stimulated by a problem (usually a rather specific one) and is directed toward finding a solution to that problem. Problemistic search increases with the amount by which performance is below aspiration level. Firms with this type of search consider those changes that alter the status quo only slightly. By contrast, innovative search increases as the firm becomes more wealthy relative to other firms in the population. Innovative search may be focussed more widely and can lead to fundamental change (Mezias&Lant, 1994) .
- Innovation type: process or product innovators;
- Innovation level (incremental/radical) differentiating for two types of innovation: process and product innovations.

The dependent variable - patterns of interaction - is estimated with two different indicators:

- items indicating the *level of cooperation* that is to say the extent into which actors within the focal firms and external to it, cooperate in the context of innovation processes by contributing ideas or techniques. Here the actors are the same as those mentioned in figure 1, and table 3;
- items indicating the *level of knowledge transfer* associated with the routine supplies, that is to say the extent into which the focal firms as users receive knowledge of their suppliers and as an innovating producer transfers knowledge to his customers. Here the actor set is restricted to the actors in the value chain: suppliers and customers.

This set of variables allows us to rethink Lundvall's hypotheses 2 by infusing our specifications of technological dynamics.

I. *Supplier dominated and scale intensive focal firms interact less frequently with the actor set than focal firms in science based industries and specialised suppliers.*

II. *Focal firms with lower levels of problemistic search activities interact less frequently with the actor set than focal firms with higher levels of search activities.*

III. *Focal firms with lower levels of innovative search activities interact less frequently with the actor set than focal firms with higher levels of search activities.*

IV. *The patterns of interaction between the focal firms and the actor set are less frequent in the case process innovations than in the case of product innovations.*

V. *Radical innovations are associated with a higher frequency of interaction between the actor set and the focal firm than incremental innovations.*

Although there is a considerable amount of empirical research available, it does not really fit our purposes because none of it made a comparative estimate of the relative frequency of interaction between focal firms and actors in the actor set. This implies that our research has an exploratory character, although it builds on ideas of former innovation research.

Research design

Sample

A survey was administered to industrial firms with five or more employees in the region of North Brabant (a province in the southern part of the Netherlands). The data gathering took place between December 1992 and January 1993.

The data gathering was performed in a region with typical features. This region is one of the most industrialized regions in the Netherlands. In 1992 the total number of jobs in manufacturing was roughly 210,000, i.e. the manufacturing sector share of employment in the region was 28.8% (The Netherlands, 19.5%). The population of firms in the region consists of a mix of small, medium-sized and large enterprises. Furthermore, the manufacturing sector has shown a relatively high R&D and export performance (Meeus & Oerlemans,1995). Because technological activity is an important issue in this article, industrial firms were grouped according to Pavitt's taxonomy (1984). These criterions were applied to the responding firms by Oerlemans (1996).

Our sample is a fairly reliable representation of the population of industrial firms in the region North Brabant. The maximum deviation between the proportions in the population and in the usable response is within 8%-boundaries. The mean deviation between the percentages in the sample and in the response is 6.4%-points.

Table 1 Population and sample divided in Pavitt sectors

Pavitt sector	Population (%, N)	Total Sample (%, n)	Sampleof Innovating Respondents
Supplier Dominated	33.5% (1.028)	25.7% (149)	22.9% (92)
Scale Intensive	41.1% (1.261)	36.1% (209)	34.1% (137)

Specialised Suppliers	13.6% (478)	21.4% (124)	22.1% (89)
Science Based	11.8% (363)	16.8% (97)	20.1% (84)
Total	100% (3.069)	100% (579)	100% (402)

Measurement

There are two sets of variables in our hypotheses: 1) independent variables measuring the rate of innovation, 2) dependent variables measuring patterns of interaction.

Table 2 Measurement of independent variables respresenting technological dynamics

Definitions, name of variables		**Indicators, calcualtion of scores, range**
Sector in which firm is active: Pavitt sectors		Supplier Dominated :agriculture, housing, private services, traditional manufacture Scale Intensive: bulk materials, assembly Specialised Suppliers: machinery and instruments Science based: electronics, electrical, chemicals
Search Types	Problemistic search : the extent into which firms innovate due to deficiencies in products and processes	Reasons to innovate were: • to solve technical product deficiencies • to solve technical production problems Scores 3) regularly, 4) often, 5)always were counted. Range is 0 (lowest)-2(highest).
	Innovative search: the extent into which firms innovate due to technical or market opportunities	Reasons to innovate were: • discovery of new market needs • technical idea, invention Scores 3) regularly, 4) often, 5)always were counted. Range is 0 (lowest)-2(highest).
Innovation Type: what kind of innovation did the firm concentrate on?		Firms where asked which type of innovation they emphasized in their innovation policy: 1 only process innovations 2 more process than product innovations 3 as much process as product innovations 4 more product than process innovations 5 only product innovations
Innovation Levels	Product Innovation Level of: the extent into which firms alter product features	Firms could answer: 1 incremental improvement of product features 2 radical change of product features Range is 1 (incremental) – 2 (radical).
	Process Innovation Level: the extent into which firms alter technical characteristics of their production processes	Firms could answer: 1 incremental improvement of production features 2 radical change of production features. Range is 1 (incremental) – 2 (radical).

Table 3 Measurement of dependent variable patterns of interaction: levels of cooperation, resp. levels of knowledge transfer

Definition, name of variable	**Indicator, range of scores**
Level of cooperation within and between the focal firm (the responding firm) and the actor set: the extent into which actors within the firm, and actors inhabiting the regional innovation system contribute to the innovation process of the focal firm by bringing up ideas, or participate actively	The focal firms were asked to report whether the following actors contributed to their innovation processes: • Trade Organisations • Regional Innovation Centres • Chambers of Commerce • National Centre of Applied Research (TNO) • Consultancy Firms • Professional Secundary Education • Higher Professional Education • Eindhoven Technical University • Other Universities • Important Buyers • Important Suppliers • Competitors The respondents could score their contribution in terms of frequencies ranging from 1) never, 2) sometimes, 3) regularly, 4) often, 5) always.
Level of knowledge transfer associated with the routine supplies: the extent into which the focal firms as a user receives knowledge of his suppliers and as an innovating producer transfers knowledge to his customers	The focal firms were asked to report the extent into which suppliers transfer knowlege to them, and the extent into which the focal firm as a producer transfers knowledge to his customers. Four items about knowledge transfer in the course of supplies had to be scored: • for suppliers of raw material • for suppliers of components and spare parts • for suppliers of machines and equipment • for the supplies to their own customers The respondents could score their contribution in terms of frequencies ranging from 1) never, 2) sometimes, 3) regularly, 4) often, 5) always.

Analyses

In this paper we restrict our analyses to descriptive, exploratory analyses testing the bivariate relations between technology dynamics on the one hand, and patterns of interaction on the other hand. The goal of our analyses is to test the discriminatory value of the variables measuring the rate of innovation for the patterns of interaction.

Due to the level of measurement of our variables – ordinal rank scores – we will apply only non-parametric analyses. Systematically we will analyse to what extent focal firms from different Pavitt sectors, focal firms with different levels of problemistic, innovative search activities (low-high), focal firms concentrating on different types (process, product) and levels of product and process innovation (incremental, radical) differ with regard to the contribution of the 16 actors to their innovation processes, and with regard to their knowledge exchange with their suppliers and customers.

The Friedman test is the nonparametric equivalent of a one-sample repeated measures design or a two-way analysis of variance with one observation per cell. Friedman tests the null hypothesis that k related variables come from the same population. For each case, the k variables are ranked from 1 to k. The test statistic is based on these ranks.

The Kruskal-Wallis H test, an extension of the Mann-Whitney U test, is the nonparametric analogue of one-way analysis of variance and detects differences in distribution location.

Results

As a general result (Table 7 and 8 in the Annex) the innovation process of the focal firms seems to be affected most by internal actors (R&D, sales, and production) and actors directly involved in the value chain (customers, suppliers). Obviously the rewards of the contribution of higher education, innovation centres and the National Centre for Applied Research to the innovation process of the focal firms are too moderate to produce strong linkage with the focal firms. The loose coupling with the regional innovation centres, universities and professional education, the national centre of applied research can be interpreted as Granovetter's weak ties. They offer a variety of technology sources which is not effectively explored or utilised by the focal firms.

Non-parametric analyses of the relation between technological dynamics (Pavitt sectors, search types, innovation types, levels of innovation) and levels of cooperation

Table 4 **Non-parametric analyses of the relation between technological dynamics (Pavitt sectors, search types, innovation types, levels of innovation) and levels of cooperation between actors within and external to the focal firm**

Actor	Sector	Rank sign.	Problemistic search	Rank sign.	Innovative search	Rank sign.	Innovation type	Rank sign.	Product innovation level	Rank sign.	Process innovation level	Rank sign.
Sales	Supplier	2	0	3	0	3	process	2	incremental	2	incremental	2
	Scale	4	1	2	1	2	product	1	radical	1	radical	1
	Special	3	2	1	2	1						
	Science	1										
	K-W	ns	K-W	ns	K-W	<.000	M-W	<.01	M-W	<.001	M-W	<.10
R&D	Supplier	4	0	3	0	3	process	2	incremental	2	incremental	2
	Scale	3	1	2	1	2	product	1	radical	1	radical	1
	Special	2	2	1	2	1						
	Science	1										
	K-W	ns	K-W	<.000	K-W	<.000	M-W	<.05	M-W	<.01	M-W	<.05
Purchase	Supplier	4	0	3	0	3	process	2	incremental	1	incremental	1
	Scale	3	1	2	1	2	product	1	radical	2	radical	2
	Special	2	2	1	2	1						
	Science	1										
	K-W	ns	K-W	ns	K-W	ns	M-W	ns	M-W	ns	M-W	ns
Production	Supplier	1	0	3	0	2	process	1	incremental	1	incremental	2
	Scale	3	1	2	1	3	product	2	radical	2	radical	1
	Special	4	2	1	2	1						
	Science	2										
	K-W	ns	K-W	<.01	K-W	ns	M-W	<.000	M-W	<.10	M-W	ns
Trade Organisa-ions	Supplier	1	0	3	0	3	process	1	incremental	1	incremental	1
	Scale	2	1	2	1	2	product	2	radical	2	radical	2
	Special	4	2	1	2	1						
	Science	3										
	K-W	<.05	K-W	ns	K-W	ns	M-W	<.10	M-W	ns	M-W	ns
Innovation Centres	Supplier	4	0	1	0	3	process	1	incremental	1	incremental	1
	Scale	3	1	3	1	2	product	2	radical	2	radical	2
	Special	1	2	2	2	1						
	Science	2										
	K-W	ns	K-W	ns	K-W	ns	M-W	ns	M-W	ns	M-W	ns

Chambers of Commerce	Supplier Scale Special Science	4 1 2 3	0 1 2	3 2 1	0 1 2	2 3 1	process product	1 2	incremental radical	1 2	incremental radical	1 2
	K-W	ns	K-W	ns	K-W	ns	M-W	ns	M-W	ns	M-W	<.10
TNO	Supplier Scale Special Science	2 1 3 4	0 1 2	3 2 1	0 1 2	3 2 1	process product	1 2	incremental radical	1 2	incremental radical	2 1
	K-W	ns	K-W	ns	K-W	<.10	M-W	ns	M-W	<.05	M-W	ns
Consultancy firms	Supplier Scale Special Science	1 3 4 2	0 1 2	3 2 1	0 1 2	3 1 2	process product	1 2	incremental radical	2 1	incremental radical	1 2
	K-W	ns	K-W	ns	K-W	ns	M-W	<.10	M-W	ns	M-W	ns
Professi-onal Secondary Education	Supplier Scale Special Science	4 3 1 2	0 1 2	3 2 1	0 1 2	3 2 1	process product	2 1	incremental radical	2 1	incremental radical	2 1
	K-W	ns	K-W	<.01	K-W	<.01	M-W	ns	M-W	<.10	M-W	ns
Higher Profes-sional Education	Supplier Scale Special Science	4 2 1 3	0 1 2	3 2 1	0 1 2	3 2 1	process product	1 2	incremental radical	2 1	incremental radical	2 1
	K-W	ns	K-W	<.000	K-W	<.05	M-W	ns	M-W	ns	M-W	ns
Eindhoven University of Techno-logy	Supplier Scale Special Science	4 2 1 3	0 1 2	3 2 1	0 1 2	3 1 2	process product	2 1	incremental radical	2 1	incremental radical	2 1
	K-W	<.10	K-W	<.10	K-W	<.05	M-W	ns	M-W	ns	M-W	<.05
Other Dutch Universi-ties	Supplier Scale Special Science	4 2 1 3	0 1 2	3 2 1	0 1 2	3 1 2	process product	2 1	incremental radical	2 1	incremental radical	2 1
	K-W	ns	K-W	ns	K-W	<.05	M-W	<.10	M-W	<.01	M-W	<.05
Customers	Supplier Scale Special Science	3 4 2 1	0 1 2	3 2 1	0 1 2	3 2 1	process product	2 1	incremental radical	2 1	incremental radical	1 2
	K-W	<.001	K-W	<.001	K-W	<.000	M-W	<.05	M-W	<.05	M-W	ns
Suppliers	Supplier Scale Special Science	1 3 4 2	0 1 2	3 2 1	0 1 2	3 2 1	process product	1 2	incremental radical	2 1	incremental radical	2 1
	K-W	<.001	K-W	<.01	K-W	<.01	M-W	<.10	M-W	<.10	M-W	ns
Compe-titors	Supplier Scale Special Science	1 2 4 3	0 1 2	3 2 1	0 1 2	3 1 2	process product	1 2	incremental radical	2 1	incremental radical	2 1
	K-W	ns	K-W	ns	K-W	<.05	M-W	ns	M-W	ns	M-W	ns

ns not significant
K-W Kuskal-Wallis test for k independent samples
M-W Mann-Whitney U test for two independent samples

H1 *Supplier dominated and scale intensive focal firms interact less frequently with the actor set than focal firms in science based industries and specialised suppliers.*

Sixteen bivariate relations were tested by making a comparison between the relative contributions of actors to the innovation process of firms belonging to different Pavitt sectors.

This hypothesis is only partially confirmed. Four of the sixteen actors taken into consideration have significantly different mean ranks. It regards: the contributions of trade organisations, of Eindhoven University of Technology, of customers, and suppliers. So in our opinion we should reject a lundvallian interpretation of Pavitt's sector classification in terms of the specialised suppliers and science based industries representing a higher level of technologcial dynamics which evokes higher levels of cooperation in general. After all, the pattern of the rankings did not reveal this clear divide between the sectors. It is interesting however that there is partial confirmation both for the ideas of Pavitt, as well as for those of Lundvall and Von Hippel. Von Hippel and Lundvall were right about the interaction and linkage with the customers. There the specialised suppliers and science based industries have the strongest linkage. For the interaction and linkage with the suppliers the pattern is different. Here Pavitt's findings on suppliers as a main source of technology are confirmed. For the production intensive industries, Pavitt (1984) found that esp. production, suppliers and R&D provided sources for technology. This is not reflected in our findings. There is no difference between the Pavitt sectors with regard to the strength of relations with these actors. The contributions of R&D, and production are equal for all Pavitt sectors, while the influence of suppliers in scale intensive industries is relatively low compared to their influence in other sectors. Nor were Pavitt's findings on the linkage of science based industries with public science, production and R&D confirmed either.

H2 *Focal firms with lower levels of problemistic search activities interact less frequent with the actor set than focal firms with higher levels of problemistic search activities.*

Sixteen bivariate relations were tested by making a comparison between the relative contributions of actors to the innovation process of firms showing different levels of problemistic search activities.

In seven of the sixteen bivariate relations tested, there were significant differences between mean rank scores of the actors. These differences suggest therefore that this kind of representation of technological dynamics indeed supports Lundvall's hypothesis that higher technological dynamics induce more cooperation. This applies to the R&D and production department, three out of four educational institutions, and to the actors in the value chain.

H3 *Focal firms with lower levels of innovative search activities interact less intensively with the actor set than focal firms with higher levels of innovative search activities.*

Sixteen bivariate relations were tested by comparing the relative contributions of the actor set to the innovation process of focal firms, between groups of focal firms with different levels of innovative search activities. In 10 out of 16 tested bivariate relations there were significant differences in the strength of relations between focal firms and the actor set. Three of those (Eindhoven University of Technology, other universities, and competitors) did not have the expected direction of differences between ranks, and had stronger relations with firms showing intermediate levels of innovative search. This implies that for this representation of technological dynamics there is also partial confirmation of Lundvall's hypothesis.

H4 *The frequency of interaction between the focal firm and the actor set is lower for process innovators than for product innovators.*

Sixteen bivariate relations were tested by making a comparison between the relative contributions of actors to the innovation process of firms concentrating on process innovation, and firms concentrating on product innovations.

Looking at columns 8 and 9 of table 4, it becomes clear that Lundvall's hypothesis cannot be confirmed without specifying the actors with which levels of cooperation increase. Product and process innovations appear to strengthen ties selectively. For 8 of the 16 tested bivariate relations, a significant difference was found between product and process innovators.

These findings enhance a further specification of Lundvall's hypothesis on the differences between product and process concerning the levels of cooperation. Within the value chain actor set, suppliers contribute significantly more to process innovations than to product innovations. The opposite applies to customers, who contribute relatively more to the innovation process of product innovators. The internal actors – sales and R&D - contribute relatively more to product innovations, while the production department has more influence on process innovations.

H5 *Radical innovations are associated with a higher frequency of interaction between the actor set and the focal firm than incremental innovations.*

To look at product and process innovation separately, sixteen bivariate relations were tested by a comparison between the relative contributions of actors to the innovation process of firms showing different levels (incremental/radical) of innovative activity.

The distinction between radical and incremental innovation discriminates stronger for patterns of interaction between product innovators and the actor set, than for patterns of interaction of process innovators with their actor set. In table 4, column 10-12, one can see that for the product innovators, there are comparatively more significant differing mean rank scores: 8 for the product innovators, 5 for the process innovators. In that sense one could contend that radical product innovators have more explicit preferences for cooperation with members of the actor set. Especially the actors in the value chain – customers and suppliers – have stronger patterns of interaction with product innovators than with process innovators. And indeed as Lundvall predicted these actors respresent the markets separating user and producer, whereas that is not so pronounced with process innovations.

Table 5 Non-parametric analyses of the relation between technological dynamics (Pavitt sectors, search types, innovation types, levels of innovation) and levels of knowledge transfer

Knowledge transfer associated with ..	Sector	Rank sign.	Problemistic search	Rank sign.	Innova-Tive search	Rank sign.	Innovation type	Rank sign.	Product innovation level	Rank sign.	Process innovation level	Rank sign.
Supply of raw materials	Supplier	2	0	2	0	3	process	1	incremental	2	incremental	2
	Scale	4	1	3	1	2	product	2	radical	1	radical	1
	Special	3	2	1	2	1						
	Science	1										
	K-W	<.05	K-W	ns	K-W	<.001	M-W	<.05	M-W	ns	M-W	ns
Supply of spare parts and components	Supplier	3	0	2	0	3	process	2	incremental	2	incremental	2
	Scale	4	1	1	1	2	product	1	radical	1	radical	1
	Special	2	2	3	2	1						
	Science	1										
	K-W	ns	K-W	ns	K-W	<.000	M-W	ns	M-W	<.05	M-W	ns
Supply of machines and equipment	Supplier	1	0	2	0	3	process	1	incremental	2	incremental	2
	Scale	3	1	3	1	2	product	2	radical	1	radical	1
	Special	2	2	1	2	1						
	Science	4										
	K-W	<.01	K-W	ns	K-W	<.10	M-W	<.01	M-W	ns	M-W	ns
Supplies to customers	Supplier	4	0	2	0	3	process	2	incremental	2	incremental	2
	Scale	3	1	3	1	2	product	1	radical	1	radical	1
	Special	1	2	1	2	1						
	Science	2										
	K-W	<.000	K-W	ns	K-W	<.05	M-W	<.000	M-W	ns	M-W	<.05

ns not significant
K-W Kruskal-Wallis test for k independent samples
M-W Mann-Whitney U test for two independent samples

Non-parametric analyses of the relation between technological dynamics (Pavitt sectors, search types, innovation types, levels of innovation) and levels of knowledge transfer

H1 *Supplier dominated and scale intensive firms interact less frequently with the actor set than science based firms and specialised suppliers.*

This hypotheses is confirmed for the frequency of the knowledge transfer associated with supplies to customers. So focal firms in science based industries, and specialised suppliers transfer knowledge more frequently to their customers, than the focal firms in supplier dominated and scale intensive industries.

The hypothesis is rejected for the knowledge transfer associated with supplies to the focal firms. Only science based firms receive knowledge more frequently from suppliers of raw materials. This can be explained by the specific relations that the chemical industry has with these suppliers. The specialised suppliers have rank 3. For the knowledge transfer related to supplies of machines and equipment , the supplier dominated firms have the highest rank, and focal firms in the science based industries have the lowest rank. Our findings clarify that here Lundvall's hypothesis needs some specification when we are dealing with supplies to the focal firms. This could partially be achieved by infusing Pavitt's findings on sources of technology (Pavitt, 1984: 354). Our findings fit Pavitt's results on the supplier dominated industries rather well. The focal firms in the supplier dominated industries tap into the knowledge base of their suppliers especially for knowledge transfer related to supplies of raw materials, and to supplies of machines and equipment. On the other hand we could dispute some of Pavitt's findings when looking at our findings. According to Pavitt, scale intensive industries have suppliers as a source of technology. In our findings scale intensive industries have very low ranks on their knowledge transfer with all kinds of suppliers. So compared to other sectors, scale intensive industries do not build on knowledge transfer from their suppliers.

H2 *Firms with lower levels of problemistic search activities interact less frequently with the actor set than firms with higher levels of search activities.*

This hypothesis is rejected. None of the bivariate tests showed siginifcant results. So this instance of technological dynamics does not discriminate between levels of knowledge transfer.

H3 *Firms with lower levels of innovative search activities interact less intensively with the actor set than firms with higher levels of search activities.*

This hypothesis is strongly supported by our results. All tested bivariate relations were significant. Focal firms with a higher level of innovative search activity tend to receive significantly more knowledge from their suppliers, and they tend to transfer their own knowledge significantly more to their customers.

H4 *The frequency of interaction is lower for process innovations than for product innovations*.

This hypothesis is not strongly supported although 3 out of 4 tested bivariate relations where significant. Our results show that the frequency of knowledge transfer from suppliers is relatively higher for focal firms concentrating on process innovations, than for focal firms that are engaged in product innovations. Lundvall's hypothesis is supported for the knowledge transfer from the focal firm to their customers. In this case product innovating focal firms have a significantly higher frequency of knowledge transfer than the process innovators.

In our view the results allow for a further specification of Lundvall's hypothesis depending on the type of actor involved. Process innovations are tied more closely to the influence of suppliers, while product innovations build more on the interaction with customers/users.

H5 *Radical innovations are associated with a higher frequency of interaction between the actor set and the focal firm than incremental innovations.*

Neither the four bivariate tests for the product innovation level, nor those for the process innovation level rendered conclusive results. Although in general the radical innovators had higher mean ranks than the incremental innovators the differences were significant only in two of the eight bivariate tests.

So this does not give very strong support for the differentiating effects that the two levels of innovation (incremental and radical) should have on knowledge transfer according to Lundvall.

Discussion

Perhaps the most important point to be discussed is that although the empirical work we reviewed was based on findings from different time frames (from the late sixties, to the early nineties) and different regions and countries (US, UK, Scandinavian countries), the customer active paradigm is still valid for firms in the nineties.

Yet our broader actor set also demands an adjustment of the customer active paradigm. Because our broadening of the actor set revealed that the rate of innovation also affected the contribution of suppliers to the innovation process of focal firms on the one hand, and from internal actors (R&D, sales, production) on the other hand.

RSI seems to have a function other than contributing to innovation processes. Probably they are confronted with the problem of every information broker functioning as a third party. They seldom play the blues, but facilitate the musician to play the blues. Also it becomes clear that their contributions are differentiated dependent on the rate of innovation. So, higher rates of innovations tend to increase the frequency of their contributions to the innovation process of the focal firms. Although there seems to be a structural hole in the North-Brabant system of innovation, forward and backward linkages as well as the other types of out-of-firm interaction feed much of the learning needed for innovation.

Looking at the different indicators for the rate of innovation and their discriminatory value than the 'search' variables have added some very interesting insights. the level of innovative search activities especially proved to have a relatively high discriminatory value for both dependent variables. The level of problemistic search activities turned out to have the same discrimanatory value for the level of cooperation, but had no discrimanatory value for the frequency of knowledge transfer with actors in the value chain. This is not what we expected. The only interpretation we could think of, is that idea generation is something qualitatively different from knowledge transfer. When a firm is solving problems created by itself, a supplier or a customer could offer some ideas. However in that phase of the innovation process (product is sold and implemented) a supplier or a customer is probably not able to transfer knowledge easily because the focal firm itself ought to have the knowledge to solve the technical deficiencies of its products.

In general our findings support Lundvall's ideas on the rising complexity of knowledge associated with higher rates of innovation, inducing a higher frequency of interaction only to a certain extent. It seems restricted to a certain part of the actor set. From the independent variables used, it seems to us less appropriate to apply the Pavitt taxonomy. Probably the level of aggregation is too high, although we are still convinced that this sector classification indicates a difference in technological dynamics. It should be helpful to disaggregate to chemicals and electronics and then re-analyse our data, to see if that gives better results. Besides the Pavitt classification of technological dynamics, it seems to us that the distinction between types of innovation is disputable. Although the basic idea is rather straightforward we found out that these different innovation types

induce interaction with specific types of actors. The clearest example is that process innovators interact more frequently with suppliers, while product innovators interact more frequently with customers. Since we redefined with our actor set from the dyad (firm with its customers) to a tryad (supplier - focal firm - user) there is also a market defined in the backward linkages from suppliers to the focal firm. Because of this finding it seems appropriate to us to adjust this hypothesis of Lundvall.
Although radicalism of the innovation in general does discriminate between the levels of cooperation, and knowledge transfer, its effects are restricted to a specific set of actors. Our findings with regard to the hypotheses on levels of innovation support Lundvall's ideas. Firms which execute product innovation more radically have a rather broad actor set involved in their innovation process, compared to process innovators.

Summary and conclusions

In table 6 a summary is given of the main findings for every hypothesis we have tested. These findings are rather straightforward. In general Lundvall's ideas are given partial support, and they are supported most convincingly by the level of innovative search activity.

Table 6 Overview of major findings for separate hypotheses

Hypotheses	**Patterns of interaction between focal firms and the actor set**	
	Levels of cooperation (complete actor set)	**Levels of knowledge transfer: kt (actors in value chain)**
H1 Pavitt sectors	Partial confirmation (only for customers)	Partial confirmation (1 actor: kt customers)
H2 Problemistic search	Partial confirmation (7 actors: R&D, production, PSE, HPE, EUT, customers, suppliers)	Rejection
H3 Innovative search	Partial confirmation (7 actors: sales, R&D, TNO, PSE, HPE, customers, suppliers)	Complete confirmation (all actors)
H4 Type of innovation	Partial confirmation (5 actors: sales, R&D, production, trade org., cons. firms, other Dutch universities, customers, suppliers)	Partial confirmation (1 actor: kt to customers)
H5 Level of innovation		
Product innovation	Partial confirmation (6 actors: sales, R&D, PSE, other Dutch universities, customers , suppliers)	Partial confirmations(1 actor: kt from suppliers of spare parts and components)
Process innovation	Partial confirmation (4 actors: sales, R&D, EUT, other Dutch universities)	Partial confirmation (1 actor: kt from focal firms to customers)

PSE: professional secundary education
HPE: higher professional education
EUT: Eindhoven university of Technnology
TNO: National Centre for Applied Research

Do we have new micro-foundations for a theory on systems of innovation? No, we do not, we have only extended the original ideas of Lundvall, and can now be more specific on our account for patterns of interaction within a system of innovation. The extension of the actor set showed two things. Internal department, as well as actors in the value chain, contribute more frequently to the innovation process when the rate of innovation increases. But also the fragility of the relational network between focal firms and the knowledge infrastructure, and the intermediary organisations emerged, in this case of a regional innovation system. We also found some very interesting variables with a relatively high discriminatory value for patterns of interaction in a regional innovation system, especially innovative search activity. Since, we've already reported in another paper (Oerlemans, Meeus, Boekema, 1998), to what extent external sources of technology, increase the innovative performance of firms, these micro analyses have considerable value in deepening the insights in the functioning of regional innovation systems. The organising capacity, and competitiveness of firms indeed depends on a *variety of* forward and backward linkages, dependent on the type, and level of innovation a firm is doing.

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ANNEX

Table 7 **Descriptive statistics of the relation between technological dynamics (Pavitt sectors, search types, innovation types, levels of innovation) and levels of cooperation between actors within and external to the focal firm (% regular, often, always)**

Actor	Sector	%	Proble-mistic search	%	Innova-tive search	%	Innova-Tion Type	%	Product innovation level	%	Process innovation level	%
Sales	Supplier	66.3	0	55.4	0	52.7	Process	38.1	incremental	59.3	incremental	63.0
	Scale	57.7	1	63.4	1	63.1	Product	70.4	radical	69.1	radical	77.8
	Special	56.7	2	69.7	2	87.7						
	Science	71.4										
R&D	Supplier	40.2	0	36.2	0	37.7	Process	21.4	incremental	44.6	incremental	47.1
	Scale	47.4	1	39.4	1	52.5	Product	47.9	radical	57.4	radical	60.5
	Special	42.2	2	60.0	2	58.1						
	Science	53.6										
Purchase	Supplier	21.7	0	19.8	0	19.8	Process	19.0	incremental	24.0	incremental	25.2
	Scale	21.9	1	28.2	1	27.0	product	28.2	radical	29.4	radical	21.0
	Special	24.4	2	27.1	2	31.1						
	Science	29.8										
Production	Supplier	56.5	0	45.8	0	54.6	process	69.0	incremental	57.0	incremental	53.8
	Scale	55.5	1	53.5	1	49.2	product	29.6	radical	66.2	radical	44.4
	Special	50.0	2	65.8	2	64.9						
	Science	57.1										
Trade	Supplier	12.0	0	7.3	0	6.8	process	26.2	incremental	8.1	incremental	5.9
Organisa-	Scale	8.8	1	5.6	1	9.0	product	5.6	radical	7.4	radical	1.2
ions	Special	1.1	2	8.4	2	6.8						
	Science	7.1										
Innovation	Supplier	2.2	0	5.1	0	3.9	process	4.8	incremental	4.7	incremental	4.6
Centres	Scale	4.4	1	2.8	1	6.6	product	7.0	radical	2.9	radical	4.9
	Special	5.6	2	5.2	2	4.1						
	Science	7.1										
Chambers	Supplier	2.2	0	1.7	0	2.4	process	0.0	incremental	3.5	incremental	3.4
of	Scale	2.2	1	2.8	1	1.6	product	1.4	radical	1.5	radical	3.7
Commerce	Special	4.4	2	3.9	2	5.4						
	Science	2.4										
TNO	Supplier	2.2	0	2.8	0	2.4	process	4.8	incremental	3.5	incremental	4.2
	Scale	3.6	1	2.8	1	4.1	product	1.4	radical	1.5	radical	0.0
	Special	4.4	2	3.2	2	2.7						
	Science	1.2										
Consultancy	Supplier	9.8	0	7.3	0	9.2	process	9.5	incremental	9.7	incremental	9.7
firms	Scale	9.5	1	8.5	1	7.4	product	2.8	radical	7.4	radical	6.2
	Special	6.7	2	9.0	2	6.8						
	Science	6.0										
Professi-	Supplier	2.0	0	1.7	0	1.4	process	2.4	incremental	1.9	incremental	2.1
onal	Scale	3.6	1	1.4	1	1.6	product	1.4	radical	2.9	radical	0.0
Secondary	Special	1.1	2	3.2	2	5.4						
Education	Science	1.2										
Higher	Supplier	5.4	0	1.1	0	4.8	process	4.8	incremental	5.0	incremental	2.9
Profes-	Scale	5.8	1	4.2	1	4.1	product	2.8	radical	8.8	radical	7.4
sional	Special	2.2	2	11.6	2	10.8						
Education	Science	9.5										
Eindhoven	Supplier	2.2	0	2.8	0	1.9	process	0.0	incremental	2.3	incremental	3.8
University	Scale	5.8	1	2.8	1	5.7	product	2.8	radical	7.4	radical	3.7
of	Special	2.2	2	4.5	2	4.1						
Technology	Science	2.4										
Other	Supplier	2.2	0	2.8	0	2.4	process	0.0	incremental	3.5	incremental	4.6
Dutch	Scale	7.3	1	5.6	1	4.9	product	2.8	radical	5.9	radical	4.9
Universi-	Special	2.2	2	4.5	2	6.8						
ties	Science	2.4										
Customers	Supplier	60.9	0	45.2	0	48.3	process	42.9	incremental	53.1	incremental	53.4
	Scale	41.6	1	43.7	1	53.3	product	54.9	radical	54.4	radical	65.4
	Special	57.8	2	69.0	2	71.6						
	Science	63.1										
Suppliers	Supplier	39.1	0	16.9	0	16.4	process	31.0	incremental	23.3	incremental	20.2
	Scale	41.6	1	29.6	1	31.1	product	15.5	radical	33.8	radical	35.8
	Special	57.8	2	33.5	2	41.9						
	Science	63.1										
Compe-	Supplier	18.5	0	7.9	0	6.3	process	11.9	incremental	11.2	incremental	11.3
titors	Scale	13.9	1	14.1	1	18.9	product	7.0	radical	17.6	radical	11.1
	Special	8.9	2	16.1	2	17.6						
	Science	6.0										

Table 8 **Descriptive statistics of the relation between technological dynamics (Pavitt sectors, search types, innovation types, levels of innovation) and levels of knowledge transfer(% regular, often, always)**

Knowledge transfer associated with ..	Sector	%	Problemistic search	%	Innova-Tive Search	%	Innovation type	%	Product innovation level	%	Process innovation level	%
Supply of raw materials	Supplier	47.1	0	36.1	0	37.4	process	46.2	incremental	43.0	incremental	38.3
	Scale	37.3	1	36.7	1	38.7	product	23.6	radical	49.2	radical	48.6
	Special	35.9	2	53.6	2	67.7						
	Science	56.7										
Supply of spare parts and components	Supplier	50.8	0	48.9	0	50.3	process	48.0	incremental	49.2	incremental	46.9
	Scale	46.2	1	50.0	1	47.8	product	61.4	radical	58.7	radical	69.1
	Special	59.3	2	61.7	2	74.1						
	Science	61.4										
Supply of machines and equipment	Supplier	84.9	0	70.0	0	71.6	process	87.5	incremental	73.8	incremental	67.1
	Scale	71.3	1	76.6	1	70.0	product	57.6	radical	71.0	radical	72.2
	Special	67.5	2	72.9	2	78.1						
	Science	64.4										
Supplies to customers	Supplier	41.3	0	49.7	0	51.2	process	42.9	incremental	52.7	incremental	58.0
	Scale	51.1	1	60.6	1	54.1	product	70.4	radical	64.7	radical	66.7
	Special	70.0	2	60.0	2	70.3						
	Science	63.1										

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