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Knowledge networks, which roles for regions and for different communication modes?

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KNOWLEDGE NETWORKS OF INNOVATIVE COMPANIES: WHICH ROLE FOR LOCAL LEARNING?

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Abstract. In this paper we present the first results of an empirical study on the spatial structure of knowledge networks of innovative companies. We address the question whether – given an increased use of information and communication technology (ICT) - knowledge networks of innovative companies are largely local (regional) and local knowledge spillovers matter for most innovative companies. First, we pay attention to theory of agglomeration economies, particularly knowledge spillovers, and connect this with resource-dependence views on the growth of companies. We then present the results of an empirical analysis of young, innovative companies in various city-regions in the Netherlands. The sectors involved are medical biotechnology, ICT-services, and mechatronics (optronics). In a comparative study of 21 companies we use rough set analysis to increase understanding of factors that cause differences in the spatial lay-out of knowledge networks. Based on the results, we foresee that cities can improve their attractiveness in terms of knowledge supply into three directions: (1) to provide easy access to knowledge in global networks (ICT nodes and international airports), (2) to provide accommodation or land close to such nodes to enable cluster formation and to preserve high-quality in the labour market, and (3) to facilitate the process of spin-off from local universities, other knowledge institutes, and local large companies.

Key words: Innovative companies, knowledge networks, agglomeration economies, resource-based views, the Netherlands, rough set analysis.

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1. Does space matter in knowledge networks?

The potential impacts of information and communication technologies (ICTs) on space have attracted attention from many researchers and policymakers in urban geography, urban economics and planning (e.g. Glaeser, 1998; Graham, 1998; Malecki, 2002; van Oort et al., 2003). Some of them suggest that ICTs (particularly the Internet) are profoundly changing the space-economy. The use of ICTs in business transaction means a quicker and denser communication and a tighter co-ordination within and between companies, and between companies and customers. Through their “distance shrinking” impact ICTs allow for outsourcing and relocation of a larger amount of activities and with larger distances involved than in previous times. In addition, the use of ICTs enables a shortening of value chains by the elimination of wholesale and retail activities, and this affects particular places. Also, the rise of new types of companies (virtual or network-based) has been addressed, i.e. companies that have a minimum of tangible assets of their own and organise assets at other companies’ places (contractors, partners) in a flexible and loosely coupled way, thereby heavily using ICTs. Such companies seem to have more degrees of freedom in their location behaviour than traditional companies and can avoid costs of congestion in large cities. Altogether, there seems a trend of decreasing importance of physical distance in the spatial organisation of economic activities. Economic value is transmitted across physical space at zero marginal costs and agglomeration of economic activities is not necessary because it does not add to production growth and economic externalities anymore (e.g. Borja and Castells, 1997; Tabuchi, 1998). In this scenario, companies become increasingly “footloose” leading to spatial dispersal.

The influence of ICTs and the Internet on the spatial organisation of business operations is based on various unique and far-reaching characteristics of the Internet self (Kenney and Curry, 2001). First, it provides an increased access to many places around the globe. Addresses connected via the Internet are almost unlimited and almost equally accessible. Accordingly, producers and consumers are able to search of the best price/quality of inputs and consumer products in the world, and producers can make themselves known to a global market. The second important feature is interactivity, such as in information feedback loops between producers and consumers in the composition of a product or in monitoring by suppliers of product use (remote diagnostics). A third and probably the most powerful feature is intelligence. Intelligence is the ability to collect information across the network, to store and process the information, and utilise the results in one node or redistribute the results across the network. These activities include search functions, selection functions (decision support), functions to connect in a selective way, and data-analysis including data-mining and monitoring, etc. These functions have already led to new services between producers and customers (customer services) since the former are able to monitor customers’ shopping behaviour and moving preferences. In addition, new relations between producers and suppliers have emerged based on the sharing of knowledge using sophisticated electronic knowledge management systems.

At the same time, it is said that the use of ICTs is still limited due to various practical problems. There seems only substitution between physical and virtual if the communication and connected economic activity are non-material and sufficiently standardised, and if there is sufficient trust between the interacting partners. If the interactions are concerned with negotiation and unique problem-solving, or with risk-taking, electronic communication is facing basic shortcomings and too high costs (e.g. van Staden and Verhoest, 2001). This

would mean that cities remain important in attracting innovative companies and that agglomeration economies remain a key attraction factor, particularly knowledge spillovers (e.g. Audretsch, 1998). However, barriers may be moving in the quality of communication technologies themselves, leading e.g. to an increased codification of previously tacit knowledge, or in the companies working with the technologies due to an increased learning curve and cultural adjustment (Andriessen, 2003). Unfortunately, our knowledge to date is not sufficient to assess the implications of such moving barriers. There is a shortage of data about newly emerging use of knowledge sources in business operations on the micro-level of companies.

In this paper, therefore, we attempt to identify and compare the knowledge networks of young, innovative companies under the influence of ICTs. The following questions are addressed:

- 1) What is the spatial scale of the knowledge networks and how can differences be explained?
- 2) What are the implications of these findings for policies on the future of cities?

At this point it is necessary to clarify the use of concepts and definitions surrounding ICTs. ICTs are conceived of as a set of heterogeneous technologies (hardware and software) that allow for electronic (data) communication and data collecting and processing in distributed networks, including e.g. Electronic Data Interchange (EDI) and the Internet, and more complex systems of remote monitoring and computer-aided decision making in virtual networks. ICTs may have different roles in the business models of companies. We distinguish between three roles of ICTs: a) ICT-services as the product, like advanced facility sharing and call centre activity, b) ICTs as a “driver” of new business models, like in network companies and electronic commerce companies (the latter fall beyond the scope of this study), and c) ICTs as support in business operations, like EDI, web ordering, and remote design and remote services (the latter two as emerging new developments). Network companies have a few activities of their own and contract all other activities out to a network of companies (e.g. research companies, suppliers of manufactured goods, logistic companies). This model is in fact ICT-driven, because it is the technology that allows for its development and implementation.

2. Theoretical perspectives

In this section we address two types of theoretical views: (1) views derived from agglomeration theory dealing with the supply-side of cities as places of location, and (2) micro-level views on the demand of companies derived from resource-based theory. According to agglomeration theory, cities provide advantages of knowledge spillover effects and an abundant availability of knowledge workers in the labour market (Acs, 2002). Spatial concentration of activities increases the opportunities for interaction and knowledge transfer, and the resulting spillover effects reduce the cost of obtaining knowledge. In addition, knowledge workers preferably interact with each other in agglomerated environments to reduce interaction costs, and they are more productive in such environments (Florida, 2002). In this line of thinking, cities are the cradle of innovative industries. Companies in the early stages of the product lifecycle and company lifecycle – when dealing with manifold uncertainty - prefer locations where new knowledge is abundantly available for free (e.g. Audretsch, 1998; Camagni, 1991). According to resource dependence views such companies have strong needs for new knowledge, i.e. knowledge about the technology concerned, and

knowledge to deal with the market (including that for capital), but they cannot generate this knowledge by themselves. In this context, Storper and Venables (2002) distinguish between various functions of the knowledge transferred in cities, like for co-ordination, confirmation and check, and for monitoring.

It is also widely recognised that the spatial extent of knowledge spillovers is limited due to some kind of geographic borders, e.g. a daily activity system where people meet easily and where people change jobs in their careers, or smaller such as quarters in a central business district or university premises where people see each other often by chance (e.g. Rosenthal and Strange, 2001). The need for spatial proximity to enjoy knowledge spillovers seems at odds with the impacts of the recent telecommunication revolution, i.e. the costs of electronic communication have drastically declined, and advanced ICTs allow for long-distance videoconferencing, data-mining, distributed virtual design, etc.

The solution for this paradox on localisation of knowledge spillovers lies in the type of knowledge concerned (Howells, 2002). On one side, there is codified knowledge (or information) that can easily circulate electronically, like prices determined at a stock exchange and statistical data. On the other, there is tacit and contextual knowledge and these are critical in innovation processes. These types of knowledge are vague and difficult to codify and, accordingly, spread mainly through face-to-face contact of the persons involved. Tacit knowledge is transferred through observation, interactive participation and practice. Contextual knowledge is achieved through longstanding and interactive learning, often in relatively open (unstructured) processes (Bolisani and Scarso, 2000).

In modern versions of resource dependence theory it is taken for granted that companies make use of various combinations of resources (bundles), like knowledge, capital, employees and networks, to generate profits, and that their success depends both on their own capabilities and the supply of resources in their environment (Barney, 1991; Lockett and Thompson, 2001). The growth of companies is constrained if there is a shortage or weakness in the available resources, and if – in the case of non-availability - companies lack the capability to generate resources by themselves. With regard to the growth of young, high-tech companies, Reid and Garnsey (1998) distinguish between different stages in the growth, running from achieving access to resources, to mobilisation of resources, and the own generation of resources. The use of the right combination of resources at the right time in the growth path enables companies to undertake a jump in the growth (next development stage).

In this paper, we assume that young, innovative companies face a larger need for local resources (knowledge) if they undertake relatively risky activities and have a limited capability in mobilising external resources or generating resources by themselves; the latter due to for example a young age and independent position. We will come back to this in explaining the research design in the next section.

3. Research design

The research design of this study employs an inductive approach using a limited number of carefully selected case studies, to obtain a rich understanding of the spatial pattern of knowledge networks. The case study design permits a logic in the sense of “replication”, allowing the case analysis to be treated as a series of independent experiments (Yin, 1994).

This approach allows for close correspondence between theory and data, a process in which the emergent theory is grounded in the data (Eisenhardt, 1989).

The study utilises a detailed field study of 21 young, innovative companies in the Netherlands, selected from biotechnology, ICT-services and mechatronics (optronics). Data were derived from face-to-face interviews with corporate managers and, additionally, from web presentation and branch reports and journals, over an eight-month period from August 2003 to March 2004. The research design required the use of a semi-structured questionnaire in the interviews, to produce both scores in a standardised way and in-depth insights. The research design also implied that companies were selected to contain a substantial degree of variance, e.g. in terms of company size, status/position and degree of innovativeness. For example, in the biotechnology sector we selected genuine research companies (a long development path of new medicines), and companies involved in tool development and service companies (shorter development paths in innovation) (Biopartner, 2002). The variance allows to investigate the possibility of replication across cases and sectors. The selection could be based on branch information derived from particular branch journals (such as Link magazine for manufacturing), annual reports of branch organisations or societies (like in biotechnology, of BioPartner), and web presentations of companies.

The logic behind the spatial selection of the companies rests on different economic growth trends of innovative manufacturing and services in the city-system in the Netherlands in the late 1990s (e.g. Bureau Louter, 2003). The logic can be summarised as follows:

- companies in mechatronics (optronics) were selected to represent manufacturing industry in the city-region of Eindhoven which has faced a persistent increase in manufacturing industry (but a decline in routine jobs in the years that followed);
- companies in biotechnology were selected from (emerging) biotechnology clusters in the city regions of Amsterdam, Leiden and Utrecht, representing the rise of *new manufacturing* industries in cities that have faced a persistent decline of manufacturing;
- companies in ICT-services were selected from the service industry in the city-region of Amsterdam, which has faced a persistent growth of producer services.

Information from the semi-structured interviews was used to develop a case-study database as a matrix which constitutes a concise representation of the underlying field information. This multi-attribute table served as a basis for a systematic comparison of knowledge networks and differentiating factors.

4. Rough set analysis

In our study, conventional statistical analysis (such as multiple regression analysis or discrete choice modelling) cannot be applied because of the low level of measurement of some variables (categorical) and the small sample. We, therefore, make use of another technique that has increased in attention in the past years, i.e. rough set analysis (e.g. Pawlak, 1991; for details, Polkowski and Stolron, 1998). Rough set data analysis aims to perform a classification analysis on “soft” data distinguished according to various groupings. If in a causal investigation a distinction is made between stimuli (condition variables) and response (decision variables), then rough set analysis is able to identify causal linkages between classified conditions and decision variables. In our analysis we are particularly interested in the decision algorithms produced by a stepwise scanning of the data-matrix. These contain conditional statements of an “if, then” nature. Accordingly, we can identify which

conditions (combinations of attributes of the conditional variables) lead – in a logic deterministic way - to a particular state of the decision variable. The decision variable in our study is: the spatial pattern of knowledge networks.

The spatial pattern of knowledge networks was measured as the most appreciated knowledge sources and their locations. Accordingly, the companies could be classified as “mainly regional” or “mainly global”. The condition attributes were selected based on the previously indicated resource-based approach to growth of companies. Accordingly, the attributes partly refer to a different risk-profile of companies in terms of needs for and access to essential resources. In addition, we have included the generic spatial orientation of the company as apparent from supplier and customer relationships. The condition attributes are the following:

- A1) status (position)
- A2) age
- A3) size
- A4) product (manufacturing or services)
- A5) development time of innovations
- A6) general spatial orientation.

Note that the interpretation of the results of the rough set analysis is valid to the extent in which the case studies selected provide a fair representation of young, innovative, companies located in city-regions. In all cases analysed here, the accuracy and the quality of the rough set approximation appeared to be equal to 1, meaning that the reliability of the classification for the dependent variable and the overall quality are at its maximum. Apparently, the 21 cases are totally distinguishable.

Each rough set estimation produces a distinction between “core variables” and other variables. If all condition variables belong to the core, then the conclusion can be drawn that all these variables contribute to an explanation and no variable gives redundant information. Each estimation also produces a set of decision rules and for each rule the concomitant coverage. The coverage is an indicator of the strength of the rule and gives the percentage of all cases sharing a similar score on the decision variable for which the rule is true. Another indicator that can be used in the interpretation of rough set results – but referring to the strength of a condition variable - is the frequency in which such variable is included in the set of rules. In the next section we proceed with a discussion of the rough set results.

5. Are knowledge networks regional or global?

In this section we present the results of the comparative analysis of the case studies, in terms of the spatial lay-out of their knowledge networks and “explaining factors” for this lay-out. Application of the rough set methodology to the matrix including the condition variables and the decision variable, leads to a set of 11 decision rules. These fall into two parts, i.e. mainly regional as the outcome of the decision variable and mainly global as the outcome of this variable. The rules can be summarised as follows:

Mainly regional

- *Rule 1.* If companies are medium-sized or larger and have a regional orientation towards suppliers/customers, then their knowledge networks are mainly regional. This hypothesis

is supported by two companies (22.2%). They represent ICT-services companies that have strong customer ties in the region.

- *Rule 2.* If companies are independent and have a regional orientation towards suppliers/customers, then the knowledge networks are mainly regional. This hypothesis is also supported by two companies (22.2%). These represent service companies in biotechnology, with mainly customer relations in the cluster where they are located.
- *Rule 3.* If companies are an academic spin-off and develop innovations through short-time projects, then the knowledge networks are mainly regional. Also, this hypothesis is supported by two companies (22.2%). These are ICT-services companies, different from the ones mentioned under rule 1.
- *Rule 4.* If companies are very young and active in manufacturing, with a mixed regional/global orientation towards suppliers/customers, then their knowledge networks are mainly regional. Again, this hypothesis is supported by two companies (22.2%). These represent young manufacturing companies in the mechatronics (optronics) sector.
- *Rule 5.* If companies are medium sized or larger, innovate through short-term development, and have a mixed regional/global orientation towards suppliers/customers, then their knowledge networks are mainly regional. This hypothesis is supported by one company (11.1%)

Mainly global

- *Rule 6.* If companies are independent or a subsidiary, and have no specific suppliers/customers orientation, then their knowledge networks are mainly global. This hypothesis is supported by three companies (25.0%). They represent service companies (ICTs and engineering) which are partly subsidiaries of foreign companies, a situation that may contribute to the rise of global knowledge network.
- *Rule 7.* If companies are corporate spin-offs and provide services, then their knowledge networks are mainly global. This hypothesis is supported by one company (8.3%). This company represents service companies in biotechnology, which are different from the ones mentioned under rule 2.
- *Rule 8.* If companies are older and innovate through a (very) long lasting projects, then their knowledge networks are mainly global. This hypothesis faces a strong support in number of companies: five (41.7%). These companies are both in the biotechnology and mechatronics (optronics) sector.
- *Rule 9.* If companies are small and a subsidiary, then their knowledge networks are mainly global. This hypothesis is supported by only one company (8.3%).
- *Rule 10.* If companies are very young and have a global orientation towards suppliers/customers, then their knowledge networks are mainly global. This hypothesis is supported by two companies (16.7%). These companies represent both segments in biotechnology and ICTs services.
- *Rule 11.* If companies innovate by very long lasting projects, then their knowledge network is mainly global (33.3%). This rule appears almost similar to rule 8 and faces a relatively strong support (four companies).

Given the above rules and coverage, we may conclude that the strongest rule is rule 8. This means that the strongest “explanatory power” is derived from the combination of the condition variables age and development time of innovation. By taking a slightly different perspective, i.e. the most often identified attributes in the entire set of rules, we may arrive at the conclusion that the general spatial orientation (in six decision rules) and status (position) of the company (in five decision rules) are the most important ones (Table 1). According to the latter interpretation, learning seems strongly related with customer and/or supplier

relations and with networks derived from the mother organisation (subsidiary) and supporting organisation (spin-off). If we have a closer look at the type of activities associated with regional knowledge networks, then we come to the conclusion that companies that learn mainly through networks in their city-region are service companies, i.e. in ICTs and in biotechnology (supported by four decision rules).

All in all, if we consider the five rules concerning regional knowledge networks, only two of them clearly match with the assumptions in agglomeration theory. It seems that patterns of learning and knowledge exchange are complicated and considerably differentiated.

Table 1 Summary of results

	Decision variable: regional or global knowledge networks
Condition attributes	Frequency (in decision rules)
A1 Status (position)	5 out of 10
A2 Age	3 out of 10
A3 Size	3 out of 10
A4 Activity (industry, services)	2 out of 10
A5 Development time of innovation	3 out of 10
A6 General spatial orientation	6 out of 10
Direction of decision	
Number of rules that match with agglomeration theory	2 out of 5 (<i>regional network rule 2, rule 4</i>)
Indicators of strength	
Number of core variables	5 out of 6
Quality of the core	1,0
Highest coverage	Rule 8
Highest frequency	Condition variable: general spatial orientation, status (position)

6. Implications for policies on the future of cities

The results of this study indicate that regional knowledge networks go along with global knowledge networks in the same cities and in the same economic sector and that the major differentiating factors are the general spatial orientation of companies and their status (position). Given the above-indicated complexity, it is difficult to arrive at conclusions on what the results implicate for the future of cities; but there are three observations from our case studies that stand relatively clear:

1. With the increasing globalisation of customer and supplier relationships knowledge networks will increasingly become global. The strength of cities involved is accordingly, based on the quality of the access they provide to global networks and nodes, using advanced ICT infrastructure and organisations (Internet Exchange) and – more importantly - quick and safe connections with international airports. The current access supplied in Amsterdam, both in terms of ICT infrastructure and connections with Amsterdam Schiphol airport, are seen as an important asset of this city. In the city-region

of Eindhoven connections with Amsterdam Schiphol Airport by rail are seen by entrepreneurs as a major problem (but improvements are foreseen in the near future).

2. There are two categories of companies that face a regional knowledge network almost “by nature”, i.e. companies that serve a strong regional customer base in biotechnology (specialists in measurement/determination techniques) and ICT-services (advanced facility providers). The strength of cities in these cases is based on the opportunities they provide for companies to be located at a short distance from each other, such as in Science Parks-like developments (biotechnology in the city of Leiden) and on policies aimed at preservation and quality increase of local labour supply (through education, specific supply of housing and living conditions). The quality of the labour market in Amsterdam (young, flexible, internationally oriented, and multilingual) is seen by entrepreneurs as a major asset of this city.
3. In addition, knowledge relations are often local (regional) for a certain period in the lifetime of particular innovative companies, namely academic and corporate spin-offs. The strength of cities in this case resides in the opportunities created to facilitate spin-off processes (often by universities and research institutes), through knowledge interaction and supply of cheap (temporary) accommodation. This holds for each university town covered by our case studies.

If we consider the need for local knowledge spillovers in the near future, we foresee that these needs will remain, meaning a sustained importance of proximity to customers and suppliers, and academic knowledge sources facilitating mutual learning on a daily basis (Table 2). By contrast, we also support the idea that in the near future, the number of network companies will increase. Their business model is an important strategy to reduce risks of large investment in research laboratories and production facilities in an increasingly competitive (risky) market, like in mechatronics (chip machine industry) and in biotechnology (new medicines). This would mean a stronger degree of loose ties and flexibility in knowledge relations and, accordingly, a higher volatility of knowledge networks in space.

Table 2 ICTs and future needs for localised knowledge (case-studies)

Role of ICTs in business model	Knowledge needs	Need for agglomeration
ICT services as product	Need for specialised workers Need for high capacity cables and nodes (AIE, global access points) Need for proximity of customers (tacit knowledge)	A remaining strong need for agglomeration economies
ICT as a “driver” of a new business model (network company)	Need for flexible knowledge relations with various parties, e.g. suppliers and customers	Increase of volatility in knowledge networks (no agglomeration need)
ICT as support in business operations	No changes because ICTs are a limited substitution for face-to-face contact	Remaining, but maybe in a somewhat larger city-region

Finally, ICT-use as support in business operations will not lead to basic changes in knowledge networks, because ICTs are a limited substitution for face-to-face contacts. This can be illustrated with the use of videoconferencing. Our respondents indicated that major shortcomings of videoconferencing reside in a low flexibility of its use (no spontaneous use),

an artificial behaviour of the participants, and an incomplete image of the participants' faces. Electronic modes like this one are apparently still not adequate to create trust, to solve non-routine problems, to decide on taking risks, etc. Thus, existing needs for face-to-face contacts remain, but most probably these are satisfied in a somewhat larger area and take place somewhat less frequently.

7. Conclusion

In this paper we have addressed emerging knowledge networks of young, innovative, companies in the ICT-age and potential impacts on the strength of cities. In the empirical part we have compared 21 companies that were selected on factors that may influence new knowledge relationships. The methodology used was rough set analysis, which fits qualitative data and small, selective, samples, and produces a number of decision rules of the "if...., then" type. The most frequently identified attributes in the decisions rules on spatial knowledge networks are the general spatial orientation (suppliers/customers) and status (position) of the company. Thus, the spatial dimension of learning seems strongly related with customer and supplier relations and with networks derived as a subsidiary and as a spin-off company. This result is part of the complexity revealed by our study, indicating only a partial support for agglomeration theory. In terms of the future, due to a limited substitution potential of electronic communication, existing needs for agglomeration economies (particularly knowledge spillovers) seem to remain. Most probably these will be satisfied in a somewhat larger area, not only due to ICTs but also to quick transport. Changes that might be expected are caused by an increased number of network companies.

In this study, the focus has been on young and innovative companies. This means that many questions are still unanswered, e.g. concerning older and routine-based companies, and concerning changes in business relations with customers and in relations between businesses, supported or driven by ICT-use. Also, questions concerning the far future, including major progress in ICTs, were beyond the scope of this study, but point to interesting next research steps.

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