Ann Reg Sci (2007) 41:813–833
DOI 10.1007/s00168-007-0143-5

SPECIAL ISSUE PAPER

Modelling dynamics of knowledge networks and local connectedness: a case study of urban high-tech companies in The Netherlands

Marina van Geenhuizen

Received: 25 June 2005 / Accepted: 21 May 2007 / Published online: 16 August 2007

Abstract There are increasing doubts on the importance of localized knowledge and learning as benefits from a clustered location. Some empirical studies indicate that the influence of local proximity in knowledge networks stretches over larger distances than in previous times, while others suggest that local and global knowledge networks coexist. This study seeks to fill a gap in understanding how knowledge networks are shaped and how global networks may affect strength of local connectedness in a cluster. The study adopts an entrepreneurial view, drawing on a selected sample of urban innovators in the Netherlands, and employs rough set analysis and various other learning experiments. The results suggest that local/regional and global networks coexist in the urban places; this as a result of the interplay of spatial focus in the overall strategy, network capabilities and innovation intensity. With regard to local connectedness, our tentative results indicate a limited, but differentiated weakening of local linkages if knowledge networking is predominantly global. Overall, in balancing global with the local, young high-technology companies seek different ways dependent on progressing in their lifecycle and specific strategic choices.

JEL Classification M13 · O32 · L65

1 Beyond local proximity?

In studies on agglomeration economies and knowledge spillovers in clusters and dense urban places, it is widely accepted that knowledge is being created and diffused

M. van Geenhuizen (✉)
Faculty of Technology, Policy and Management, Delft University of Technology,
Delft, The Netherlands
e-mail: m.s.vangeenhuizen@tudelft.nl

in a pervasive and collective way on a local basis, facilitated by local proximity. Accordingly, young and competitive companies established on the basis of new technology are seen as enjoying the benefits from locally embedded knowledge networks and learning (Acs 2002; Audretsch 1998). The facilitation of face-to-face contacts and repeated meetings in-person by spatial proximity and proximity-based institutional endowment and social ties, allowing the transfer of tacit knowledge, and the limits to this by particular geographic borders (for example, Rosenthal and Strange 2001) are central in the arguments viewing localized knowledge spillovers and collective learning as a major benefit of clusters and dense urban environments (Capello and Faggian 2005; Maskell and Malmberg 1999; Storper and Scott 1995; Porter 2000).

Recently, however, various authors have expressed doubts on the role of local proximity in shaping knowledge relations from different theoretical angles. First, the intimate relation between local proximity and tacit knowledge transfer has been criticized based upon the idea that tacit knowledge can also be transferred over distances in global networks by travelling of persons, provided that the contextual knowledge necessary for understanding, is present, like in communities of practice and research alliances dispersed over the globe (for example, Gertler 2003). In addition, local proximity per se is not sufficient in generating tacit knowledge transfer and localized learning favourable for innovation (for example, Boschma 2005). Secondly, the general globalization of economic activity and the increased specialisation in innovation seem to exclude that all major components of knowledge are found in one and the same place (Simmie 2003). This connects with a third argument, derived from entrepreneurial views on knowledge networking in open systems and learning on the company level (Bathelt et al. 2004; Best 2001; Martin and Sunley 2002). High-technology companies do not search for local knowledge, but search for the best available knowledge in the frame of their competitive edge, and this happens on a continuum that runs from local to global places. Furthermore, companies may be different in innovation strategies and in learning capabilities, the latter including companies' different sense of cognitive proximity (Cohen and Levinthal 1990; Guiliani and Bell 2005). "Born-globals" are a specific category in this context because these employ a manifold international strategy from their inception or shortly after, owing to early achieved capabilities to access global networks (Andersson and Wictor 2003; McDougall et al. 1994). Adopting an entrepreneurial perspective means the recognition that knowledge networking by companies may be different in one and the same urban place (cluster), dependent on the types of companies present.

Meanwhile, new empirical evidence has cast doubt on a pre-eminent role of localized knowledge networking. For example, studies on research collaboration measured through publications in journals and patent citations (Johnson et al. 2006) and studies of broader knowledge relations in one of the most clustered high-technology sectors, i.e. biotechnology (Audretsch 2001). Further, Coenen et al. (2004); Lawton-Smith (2004); McKelvey et al. (2004), and Mytelka (2004) found a minor importance of local knowledge sources, or at least an equal importance of local and long distance knowledge relationships. Also, Gertler and Levitte (2005) questioned the pervasiveness of the local in biotechnology innovation. In studying other sectors, for example, oil-complex activity (Cumbers et al. 2003) and the optoelectronics industry (Hendry and Brown 2006) other authors arrived at similar results and question marks. Some studies indicate that proximity today—due to a fast transport and telecommunication—“works” over larger distances than in previous times, but remains important, while others recognise the existence of a mix of local and global learning dependent on companies’ needs and capabilities.

Despite a growing number of studies emphasizing the role of global knowledge while adopting an entrepreneurial view, few authors have attempted to better understand why some clustered companies are mainly engaged in localized learning and why others employ mainly global knowledge networks, and how these different patterns may affect companies’ connectedness in the cluster. The changes that may occur in local supplier- and customer relations and in local personal networks when the company gains mainly global knowledge input, have remained unknown to date. There may be a loss of local connectedness of the companies, or conversely, there may be a strengthening, for example, if particular local relationships benefit from new global knowledge through local diffusion.

Given the above shifting views and lack of understanding, this study takes the perspective of company-level learning. The empirical part builds on previous results (van Geenhuizen 2005) and pushes the subject further towards changes in local connectedness of companies. In other words, we particularly examine whether proximity through local linkages becomes less important as the knowledge economy expands. Using rough set analysis and various learning experiments dealing with a small sample of young, innovative companies in the Netherlands, the paper addresses two questions. First, to what extent are knowledge creation and exchange taking place in mainly local and mainly global networks, and which factors are shaping these networks? Second, how are changing knowledge networks affecting dynamics in local connectedness of companies?

The structure of the paper is as follows. It starts with a discussion of the theoretical framework (Part 2) and the research design, particularly the use of rough set analysis (Part 3). This is followed by an examination of the outcomes of the first empirical step, concerning factors in shaping knowledge networks (Part 4) and changes in local connectedness (Part 5). Next are the results of the second step, that is the application of the rough set rules found in the first step to a particular biotechnology cluster to picture and understand the knowledge networks and an in-depth exploration of changing local connectedness of biotechnology companies (Part 6). The conclusion is devoted to an evaluation of the results and some future research lines (Part 7).

2 An entrepreneurial perspective

Regional scientists have only recently started to consider learning in dense urban places and clusters as the outcome of more than physical proximity, local social ties and institutional endowment. The analysis of learning on the company-level and an emphasis on heterogeneity among clustered companies following from diversity in company-internal factors, are relatively new (see, for example, Martin and Sunley 2002). In this section, we elaborate a previously developed analytical framework (van Geenhuizen 2007) in which an entrepreneurial perspective is taken and strategies and capabilities are major components.

To seize opportunities in particular product-markets and maintain competitive edge, companies develop various strategies. This is concerned with particular types of innovations, like those supporting cost reduction, product uniqueness, or expanding in new geographic markets. Different strategies lead to different needs for resources that companies may acquire through own development or networking with other companies or organisations (Barney 1991; Lockett and Thompson 2001). For example, a research company in biotechnology requires more knowledge and investment capital and for a longer time than service companies in the same sector, particularly if the latter supply rather standardized services. Most young research companies are not able to generate these resources by themselves and rely on their networks for gaining them (for example, Manguematin et al. 2003). The analysis distinguishes between two components in a simplified analytical framework, i.e. strategy and internal capabilities:

1. *Strategy* The analysis is erected on three theoretical attributes, i.e. main activity, innovation intensity and spatial focus in the overall strategy. Main activity is included because of large differences in needs for knowledge, such as between companies in relatively standardized services serving the region and those in specialized manufacturing and cutting-edge research. In a similar vein, innovation intensity is seen as important because the stronger the intensity, the larger the chance that the best knowledge is not locally available but just in a few places across the globe (for example, Nooteboom 2000). With regard to the overall strategy, it is important to mention young innovative companies that employ such an internationalisation strategy actively from their start and build competitive advantage from resources and sales of outputs in multiple countries (Andersson and Wictor 2003; McDougall et al. 1994; Rialp et al. 2005). These companies, named born globals, tend to be relatively specialized (niche-oriented) and are endowed with the capability to access R&D channels through close collaboration with global partners. By contrast, other young companies develop an international strategy as a stepwise, gradual process in which they expand their customer markets and gain various networking capabilities over time (Madsen and Servais 1997).
2. *Capabilities* The capabilities that are relevant here are those through which a company can enter into alliances and access partners' resources and, accordingly, can overcome resource deficiencies (Chetty and Wilson 2003; Dana 2001). These capabilities rest on two company characteristics, that is, previous experience and internal intangible assets. Previous experience encompasses strategy and management experience of entrepreneurs, e.g. in the case of young corporate spin-off companies. Intangible assets include, for example, relational capability that enables to select the right network partners, and absorptive capacity that allows to recognize the value of new external knowledge, identify, acquire and absorb it (Cohen and Levinthal 1990). Different capabilities and the resulting cumulative learning processes, the latter being inherently imperfect, complex and path-dependent, contribute to heterogeneity between companies in the same urban places and clusters (for example, Dosi 1997).

Networks may be seen as a specific external source of resources (Brush 2001; Lechner and Dowling 2003). Employing networks to achieve resources has become quite common in the business world since the late 1970s (for example, Borgatti and Foster 2003; Hoang and Antoncic 2003). An increased competition and the need for flexible specialization have urged companies to reduce in-house R&D and achieve part of the knowledge from external partners. Particularly, small high-technology companies may gain cost-advantages from flexible types of knowledge networking or from contract-based research partnerships because these give them access to a varied field of knowledge without investing in all of them, thus allowing to focus internal research efforts on a limited number of promising projects (Roijakkers and Hagedoorn 2006). Networks can be perceived as a set of actors connected by a set of ties, including persons, teams and organisations. Companies establish networks or participate in existing networks if the perceived benefits outweigh the perceived costs. Some networks primarily aim at achieving the best knowledge while others include knowledge exchange and learning as an important side-effect, like in customer- and supplier relations.

Networks can take any spatial configuration from local to global. The local connectedness of companies is conceived as a state of the set of local network relations, particularly in terms of overall strength or importance. We may think of linkages with local knowledge institutes, suppliers, customers, competitors, and supportive institutes. Granovetter (1985) has introduced the notion of embeddedness for those situations in which the business relationships have a positive social loading that go far beyond simple cost-benefit analysis in decision-making between the partners concerned. In this context, various authors have put an emphasis on the role of close, special and trusting relationships as potentially beneficial to learning and innovation (for example, Uzzi 1997). Conceived in this way, local connectedness and embeddedness are different, but the latter cannot go without the former. Thus, the term connectedness is preferred and used in this paper, because it leaves open to what extent embeddedness is involved which falls beyond our scope.

In this study, the knowledge supply characteristics of the local environment are taken as given. As shown in the next part of the paper, all case studies of companies are in highly urbanized places or clusters. It is important to note that due to high levels of specialisation and globalisation, no high-technology place can satisfy all knowledge needs required by individual companies. Therefore, aside from the potential local availability of relevant knowledge, it is important to mention local available access to global knowledge relations. The latter encompasses physical access, like to an international airport and super computers, but also social access, including knowledge about the best global networks and trust and mutual understanding shared with global partners (for example, Gertler 2003; Wolfe and Gertler 2004).

3 Research design and methodology

3.1 Research setting, sampling and structure of analysis

The study used a multiple case study approach of 21 carefully selected companies. The selection aimed at representation of major categories of young, urban innovators in the Netherlands, for example, companies endowed with different organizational capability (spin-offs versus independently established companies) and companies active in different types of innovation (highly innovative in bringing global break-through innovations to market versus incrementally innovative in response to customer demand). In addition, companies were selected in three economic sectors that reflect recent developments in urban growth in the Netherlands (Bureau Louter 2003). Thus, ICT producer-services represent knowledge-based services driving the growth of large urban economies, like Amsterdam and Utrecht in the Randstad, whereas mechatronics (optronics) represent innovative manufacturing as the driver of medium-sized cities' economies in a region adjacent to the Randstad, like the city of Eindhoven. Biotechnology represents a strengthening of urban economies in the Randstad, against the trend of an overall loss of manufacturing in these economies.

The analysis was in two steps. First, rough set analysis was used as a 'causal' approach producing a set of decision rules on the occurrence of local/regional and global knowledge networks. In addition, these rules and outcomes were evaluated for implications concerning local connectedness of companies, particularly on the basis of a comparative analysis of locally oriented knowledge networking and globally knowledge networking companies. In a second step, the decision rules were applied to companies in a biotechnology cluster to identify the pattern of spatial orientation of knowledge networks and changes in local connectedness in such clusters.

3.2 Rough set analysis: principles and prediction accuracy

Rough set analysis was used because of its match with small samples, a low level of measurement of some data (i.e. categorical) and a somewhat fuzzy character of the data (e.g. Pawlak 1991, 2001; for details, see, Polkowski and Skowron 1998). A main advantage is that in rough set analysis—unlike more conventional methods such as multiple regression analysis and discrete choice models—only one assumption is made about the data, i.e. that the value of the determining factors can be categorized. Rough set analysis has increased in popularity in the investigation of company behaviour, like acquisition, failure (bankruptcy), market strategy and location-boundedness (Dimitras et al. 1999; van Geenhuizen and Nijkamp 2007; Masurel et al. 2004; Sanchis et al. 2006; Slowinsky et al. 1997).

In rough set analysis, information is presented in an information table, that is, a matrix in which rows are labelled by *objects* (in this study: companies) and columns are labelled by *attributes (variables)* (Table 1). Objects are arranged on the basis of their condition attributes (C) and decision attribute (D). These two types of attributes are analogous to the independent variables and the dependent variable like in conventional regression analysis. The condition attributes consist of the features that describe the object, whereas the value of the decision attribute contains the concepts to be learned based on the value of the condition attributes. The basic procedure in rough set analysis works through attribute reduction, i.e. finding a smaller set of attributes with the same or close classificatory power as the original set of attributes. Two basic concepts in this context are *reduct* and *core*. A reduct is the essential part of an information table (subset of attributes) that can discern all objects discernible by the original information table. A core is a common part of all reducts. On the basis of a reduced information table, *decision rules* are composed through determining the decision attributes value based

Table 1 Structure of the information table (two examples of companies)

Objects[a]	C_1	C_2	C_3	C_4	C_5	C_6	Decision attribute
	Main activity	Duration innovation projects	Spatial focus strategy	Age	Size	Position	Spatial layout
O_1	1	1	1	2	1	1	1 = Local/regional
O_2	2	2	4	2	2	4	2 = Global

C_1–C_6: condition attributes. Classes of the condition attributes: C_1: (1) services, (2) research, (3) advanced manufacturing; C_2 : (1) weeks/some months, (2) a few years, (3) longer; C_3: (1) local/regional, (2) local/regional and national, (3) local/regional and global, (4) global orientation; C_4: (1) 5 years and younger, (2) older than 5 years; C_5 : (1) < 25, (2) 25–150, (3) > 150 jobs; C_6: (1) independent, (2) subsidiary, (3) academic spin-off, (4) corporate spin-off
[a] $O_1 - O_{21}$: case studies (companies)
Source: van Geenhuizen (2007)

Table 2 Summary of results of the rough set analysis

Condition attribute	Overall frequency in rules (frequency concerning global networks)
C_1 Main activity	2 (1)
C_2 Duration of innovation projects	3 (2)
C_3 Spatial focus in overall strategy	6 (2)
C_4 Age	3 (2)
C_5 Size	3 (1)
C_6 Position	5 (3)
Indicators of strength of the information table	
Number of core variables	5 out of 6
Quality of the core	1.0
Indicators of strength of the results	
Maximal coverage of rules	41.7%
Majority of coverage (4)	22.2%

Source: Adapted from van Geenhuizen (2005)

on condition attributes values. A decision rule is presented in a "IF condition(s) THEN decision" format. The rough set procedure provides results that assess the *quality of the data* in the information table, based on the distinction between core and other attributes. If all condition attributes belong to the core, then all these attributes contribute to an explanation and no attribute gives redundant information. In our analysis, all but one condition attribute belong to the core. The quality of the analysis reaches the value of 1.0, meaning that the reliability of the classification for the dependent variable and the overall quality of the information table are at their maximum (Table 2).

Note that in various studies the *prediction accuracy* of decision rules was tested on the basis of new samples and this has revealed rather satisfactory outcomes (Annex 1). The prediction accuracy is measured as the percentage share of correctly classified companies for a number of samples. The widest range of accuracy in the listed studies is between 98.8% and 50.0% but most ranges are smaller. Average prediction accuracy is around 75%. The previous ranges and averages indicate that using decision rules to estimate the spatial layout of knowledge networks of another set of companies may approach accuracy levels that are acceptable.

3.3 Variables and measurement

Data were derived from face-to-face interviews with corporate managers and, additionally, from web presentation and annual reports of companies. 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. Information from the semi-structured interviews was used to develop the information table, serving as a basis for a systematic analysis of the spatial layout of knowledge networks (Table 1).

The two sets of attributes concerning strategic focus and internal capabilities were "translated" into measurable characteristics as follows. Main activity was measured on the basis of the categories services, research and specialized manufacturing; innovation intensity was measured through the time–length (duration) of innovation projects, ranging from a substantial number of years (10–15 years) to a few weeks, and the spatial focus in the overall strategy was measured through the focus in supplier- and customer markets, ranging from a strong local/regional focus to active globalization. In the frame of the current study, we were forced to use proxies in measuring internal capabilities, for example, age of company and company position (in terms of origin) in measuring experience. Size of the company is also included because some network capabilities may increase with size, particularly when staff capacity can be allocated to develop and elaborate network capability.

Knowledge networks were measured as 'actual relations dealing with knowledge' in the frame of innovation, for example, concerning personal networks of the manager (CEO), customers, suppliers, knowledge institutes, alliance partners, head office if subsidiaries, etc. The knowledge relations identified covered small, focused teams as well as multiple focus networks, like the ones between some company staff and customers with multiple customer relations, all relatively stable in nature.[1] The most important knowledge networks underpinning innovation were identified first and, next, the companies were classified as 'mainly local/regional' or 'mainly global' on the basis of dominance of either a local/regional or global layout. A two class classification was adopted because a more refined classification would have rendered rough set analysis less useful.

In the interpretation of the rough set results the coverage of each rule was used. The coverage is an indicator of the strength of the rules, calculated as the number of cases with a similar set of attributes and score on the decision attribute as percentage share of all cases with this score on the decision attribute. The highest level reached

[1] Other ways of measuring, using e.g., joint co-authorship of scientific publications, patent applications or citations could have been selected. The sources involved have intrinsic advantages of being based on public information, not affected by sampling dangers in company surveys, and of reflecting certain benchmark levels of novelty. However, the connection with actual utilization of the new knowledge in business practices remains weak.

Table 3 Layout of knowledge networks (21 case studies)

	Mainly local/regional	Mainly global
Nr of companies	9	12
Max share of local (%)	58	–
Max share of global (%)	–	100

Source: Adapted from van Geenhuizen (2005)

in the analysis was 41.7% (5/12), but most rules did not exceed 22.2%. In many other rough set results, the highest coverage does not exceed 50% and often just a few rules are relatively strong. Another indicator used in the interpretation is the frequency in which particular condition attributes occur in the set of rules (Table 2). The higher the frequency of occurrence, the stronger the explanatory power is.

Further, to measure the strength of local connectedness, the importance attached to five different local networks by the company was used as a proxy. These networks were concerned with knowledge institutes, suppliers, customers, labour market relations and personal relationships of the entrepreneurs. Importance was measured through stated preference using a five-point scale and change in importance (current/near future) was measured using a three-point scale. Accordingly, local connectedness was calculated as the non-weighted added sum of the five scores, whereas changing local connectedness was calculated as the added sum after assigning different weights to scores representing an increase compared with scores representing a decrease of importance.[2] Note that measured in this way, local connectedness may also include elements of embeddedness to a certain degree.

4 Factors shaping knowledge networks

The spatial layout of the knowledge networks of the sampled companies suggests a trend for co-existence, that is, particular segments of young innovative companies in urban areas employ mainly local/regional networks while other segments employ mainly global networks (Table 3). In addition, global networks seem to develop in a more pronounced way compared with local/regional networks, witness the difference in maximum shares (100 vs. 58%, respectively). This finding suggests that urban companies are never fully local/regional in their knowledge production and exchange, whereas they may be fully global in this respect.

The application of the rough set methodology has produced 11 decision rules referring to the above two classes of spatial layout. In the remaining parts of the paper, the discussion is limited to eight decision rules that are solid in that they cover companies not subject to an exceptional situation (such as the ICT crisis) (Table 4). The results can be summarized as follows (see, also Table 2).

[2] In order to articulate a decrease and increase of importance, an increase of importance was assumed to be at least 150% and a decrease of importance as 50% of the score. Of course this is arbitrary, but slight changes in these weights have not produced basically different outcomes.

Table 4 Rough set results concerning spatial layout of knowledge networks

Conditions in rules	Rules, number of cases and coverage (%); specific conditions; additional company characteristics in italics
Mainly local/regional	
Size and spatial focus in overall strategy	Rule 1: 2 cases (22.2%) Medium-sized or larger and an overall strategy with a strong local/regional orientation. *ICT services, like specialized call centres and facility providers.*
Position and spatial focus in overall strategy	Rule 2: 2 cases (22.2%) Independent position and an overall strategy with a strong local/regional orientation. *Services in biotechnology (standardized).*
Position and duration of innovation projects	Rule 3: 2 cases (22.2%) Academic spin-off and short lasting innovation projects. *ICT services aimed at non-standard problem-solving and system optimisation.*
Age, main activity, spatial focus in overall strategy	Rule 4: 2 cases (22.2%) Young, manufacturing companies without a spatial focus in the overall strategy. *Advanced optronics companies in (re)start (e.g. monitoring systems).*
Mainly global	
Position and spatial focus in overall strategy	Rule 5: 3 cases (25.0%) Independent or foreign subsidiary, without a spatial focus in the overall strategy. *ICT services (a broad range including interface development supporting e-business) and some engineering services.*
Position and main activity	Rule 6: 1 case (8.3%) Corporate spin-off and engaged in services. *Advanced biotechnology services (non-standard process optimisation) in a global network gained from parent company.*
Age and duration of innovation projects	Rule 7: 5 cases (41.7%) Older age and (very) long lasting innovation projects. *Biotechnology (medical) research and advanced optronics development (e.g. video monitoring).*
Age and spatial focus in overall strategy	Rule 8: 2 cases (16.7%) Young age and global orientation. *Biotechnology (medical) research (foreign subsidiary) and ICT services (design of digital protection software).*

Source: Adapted from van Geenhuizen (2005)

1. Overall there is no single condition attribute that has an important classification power in the spatial layout of knowledge networks, it is often a combination of two conditions. Given such combinations, two condition attributes have a strong classification power based on frequency of occurrence in the decision rules, i.e. position (in terms of origin) and spatial focus in the general strategy (five and six, respectively) (Table 2). This points to organizational capability through relations with the organization of origin (corporate or academic) and to the general spatial orientation (supplier- and customer markets) as determining factors. Other condition attributes dealing with strategies or capabilities seem less important. If we focus on mainly global networks, only position (in terms of origin) has a relatively strong classification power.
2. A relatively strong decision rule is Rule 7, referring to mainly global networks. It is supported by five case studies (a coverage of 41.7%) from different sectors, that is, biotechnology research and advanced optronics development and manufacturing. The rule says that relatively older companies engaged in (very) long-lasting innovation projects employ predominantly global knowledge

networks. Apparently, companies that develop high levels of specialization in innovation after some years of existence (between 6 and 12 years) access the knowledge they need through global knowledge networks. A strong innovation intensity tends to be an important driving force behind global knowledge networking in production and co-development with customers, like of sophisticated video-camera's (matching poor visual conditions) and in research of new medicines in collaboration with large pharmaceutical firms abroad that also provide access to emerging global markets.

3. Next in strength is Rule 5, equally referring to mainly global networks but with a lower coverage (25%) and supported by three case studies. The decision rule is somewhat vague in stating that companies that are independent or a foreign subsidiary and have no specific spatial orientation in their overall strategy, employ predominantly global knowledge networks. The companies that support this rule are active in a range of ICT services (and engineering) in which the international orientation towards the parent company or towards hardware and software suppliers is somewhat stronger than the local/regional orientation towards customers in shaping knowledge networks.
4. The decision rules referring to local/regional knowledge networks are different in that there is no strong rule and all rules have a coverage of 22%, supported by two case studies. A local/regional orientation in the overall strategy is a relatively consistent condition, while other conditions feature just in single rules, like position of academic spin-off and short-lasting innovation projects, young age (2–5 years) and specialized manufacturing (product development). With regard to main activity, most companies involved are service companies in ICT (like call centres, IT facility providers and system designers) and in biotechnology (routine and customized determination and testing). The manufacturing companies are relatively young and in early stages of product development and design, such as new applications of sensor technology (optical monitoring) and laser technology (wafer cutting machines), for which the main knowledge relations include a range of organisations in the region (university, public research institute, co-developing companies) and some organisations abroad.

With regard to global networks, the findings may be summarized as follows. Global knowledge networks tend to be mainly shaped by network capabilities derived from the parent company (concerning global customers), and by a high intensity of innovation (specialization) for which the knowledge is not locally available.

A first indication for changes in local connectedness may be derived from two company types for which an absence of a clear spatial focus in the overall strategy contributes to a specific layout of the knowledge networks. Thus, Rule 4 includes the *absence* of a clear spatial focus, which in the reality of the two case studies indicates a transition from mainly local/regional relations to more global relations, potentially implying a reduction of local connectedness. Such a development refers to companies that utilize strongly supportive local relations during their start or restart but adopt a wider global orientation in the next stage, particularly in supplying and customer relations. In turn, Rule 5, which also includes an *absence* of a clear spatial focus in the general strategy, alongside position (foreign subsidiary), may imply an increased local connectedness. Such a development refers to service companies that first depend strongly on the parent organisation abroad in terms of knowledge exchange, but, later on, increase local connectedness to better perform their task of serving the Dutch market. In the next section, the attention turns to an in-depth quantitative and qualitative analysis of local connectedness and changes herein that goes along with globalization of knowledge networks.

5 Global knowledge and delocalizing networks

The literature to date suggests only a modest understanding of ways in which globalization leads to a decreasing local connectedness in clusters. One of the few empirical studies concerning small companies indicates that local company internationalization does impact the nature of local linkages, but the effect is nuanced and affected by individual growth strategies (DeMartino et al. 2006). In this section, we discuss the outcomes of a comparative analysis of companies employing mainly local/regional knowledge networks (category 1) and companies employing mainly global knowledge networks (category 2) on current strength of local connectedness and changes in this strength. The focus is on five individual local networks (Table 5).

It appears that companies that employ global knowledge networking are *systematically* less strongly connected with local networks if differences between averages are taken into account. This holds for the current situation but also—and somewhat stronger—for the changing situation. Supplier networks are facing the largest difference between the two categories of companies in the current situation, whereas

Table 5 Average importance of local linkages (scores)

	Category 1 Local knowledge networking	*Category 2* Global knowledge networking	Difference	*F* test[a]
Current situation				
Knowledge networks	3.8	3.3	– 0.5	0.954
Supplier relations	2.9	1.9	– 1.0	4.236*
Customer relations	3.3	2.7	– 0.6	1.123
Labour relations	3.6	3.4	– 0.2	0.089
Personal relations	3.7	3.0	– 0.7	2.171
Changing situation				
Knowledge networks	4.4	3.3	– 1.1	0.189
Supplier relations	3.1	1.5	– 0.6	0.012**
Customer relations	3.8	3.6	– 0.2	0.811
Labour relations	4.5	3.7	– 0.6	0.520
Personal relations	4.3	3.0	– 1.3	0.099*

[a] one-way ANOVA test; p-values: * 0.10 confidence level; ** 0.05 confidence level; Welch and Forsythe and Brown tests produce similar results
N (companies) = 21

knowledge institute networks and personal relations of the entrepreneurs are facing the largest difference in the changing situation. The outcomes of the *F* test, however, reveal only substantial differences for supplier relations in both situations, particularly concerning the changing situation. In addition, the difference for personal relations is substantial only for the latter situation. Thus, global knowledge networking tends to enhance a process of delocalizing of cluster networks to a limited extent, except for supplier relations and personal relations.

Using a breakdown of the above two company categories into companies facing a strengthening and companies facing a weakening in local connectedness (Annex 2) suggests a broad confirmation of the previous trend. If we take a closer look into the company types that couple use of global knowledge with a decline in local connectedness, it is possible to identify two types, that is, young research companies in biotechnology that have been acquired by a foreign company (all five local networks have lost importance), and somewhat older manufacturing companies in optronics that have adopted a strong internationalisation strategy in customer markets and outsourcing networks (most local networks have lost importance). However, one may also note that (against the previous trend) two types of companies are rather strongly reinforcing local linkages while employing mainly global knowledge relations. These are foreign subsidiaries engaged in developing a regional market (Amsterdam) or the market in the Netherlands (adjacent countries) for which they need a strong local basis, and research companies that employ strong institutional links with a local research institute (knowledge commercialization by contract). These findings indeed confirm that the delocalizing of networks is not all-important and that the pattern is rather differentiated. They also show that a snap-shot of companies and networks gives a poor picture and that a longer time-perspective is preferred in the analysis to grasp *lifecycle* influences and the interplay with strategy.

The paper next moves to the second step of the analysis, in which biotechnology is used as one of the most clustered sectors of all high-technology industries as an interesting learning example concerning our preliminary findings on knowledge networks and local connectedness.

6 Knowledge networking in a biotechnology cluster

The largest and oldest biotechnology cluster in the Netherlands, Leiden, located approximately midway the cities of Amsterdam and The Hague in the Randstad is selected as the focus of the analysis. The reason is that this cluster hosts a relatively large variation of biotechnology companies in terms of age and size, and in biotechnology fields such as general and medical biotechnology basic research and routine services (testing). The origin of the cluster goes back to the opening of the Bio-Science Park, including an incubator facility in the early 1980s. Although the park was a latecomer in Western Europe, growth took off almost immediately after the establishment of a subsidiary of USA-based *Centocor* in 1985. The number of biotechnology companies in the cluster of Leiden, narrowly defined within approximately 5 km from the research hospital, medical school and relevant faculty buildings, amounted to about 27 in the beginning of 2004, including young dedicated entrepreneurial companies

(24) and three foreign subsidiaries, but excluding consultancy companies, traditional pharmaceutical industry, and medical devices.[3]

In the attempt to estimate the knowledge networks of cluster companies using the previous rough set results, we applied rules concerning the biotechnology sector itself and one rule concerning young start-ups in other research (local/regional knowledge networks); the latter to cover the large segment of young start-ups that emerged under the influence of a national support policy for biotechnology (Biopartner 2005; van Geenhuizen 2003).[4] The estimation results indicate a clear coexistence of companies employing mainly local/regional networks (52%) and companies employing mainly global knowledge networks (48%) (Table 6). The small majority of local/regional knowledge interaction rests on the presence of regionally active service-companies and very young research companies originating from the university, medical school or research hospital. Global knowledge networks are mainly associated with research companies that are somewhat older. This pattern clearly matches with the idea that companies look for the best available knowledge including local knowledge; it certainly does not match with ideas of predominantly local networking and localized learning in clusters. If we take the number of knowledge workers involved into account, the pattern is even more pronounced (92% active in global networking). Note that the previous conclusion does not basically change if a prediction accuracy of 75%, causing a potential underestimation in the two classes of companies, is taken into account.

The remaining part of the paper draws on insights into representative biotechnology companies, their knowledge networks and local connectedness, achieved from in-depth interviews and company documentation. By adopting a knowledge development approach (Cooke 2004, 2005) it appears that the local knowledge infrastructure plays a crucial role in the first stage of research start-ups, but soon, a further exploration and examination of the new knowledge takes place outside the cluster of Leiden, in mainly global networks, including big pharmaceutical industry and collaboration with medical schools, academic hospitals and research institutes in widely different places. For example, development programs of Leiden-based *Crucell* (originated from two predecessor companies in 2000) include collaborations with *Sanofi Pasteur*, the US National Institute of Health, and Harvard University, aside from a strong collaboration with Dutch *DSM-Biologicals*. Somewhat younger Leiden-based *to-BBB* (originated as a spin-off from Leiden University in 2003) stepped into global agreements with *Genmab* (Denmark) and US based *Biogen Idec* two years after its start, aside from collaboration with Leiden University and Leiden-based TNO-Pharma. There are various reasons for an early establishment of global knowledge networks in medical biotechnology, that is, the need for approval of new drugs in the USA (FDI), marketing access mainly through foreign companies and, due to high levels of specialization, the

[3] When one takes a broader area as a poly-nucleated cluster with a maximum distance of approximately 65 km, then also the cities of Delft, Rotterdam, Amsterdam and Utrecht are included, the latter three with their own academic hospital and medical school. Accordingly, the number of dedicated biotechnology companies is larger, that is 62.

[4] To apply the relevant decision rules to the population of the Leiden cluster additional information about the companies using sector reports on biotechnology (Biopartner 2004, 2005) and open company documentation were used.

Table 6 Knowledge networks (estimated) in the biotechnology cluster of Leiden

Company attributes	Network	Nr of companies[a]	Nr of knowledge workers
Services; independent position; a local/regional focus in overall strategy (Rule 2).	Local/regional	8	80
Research; very young start-ups; without a focus in overall strategy (Rule 4).	Local/regional	6	35
Advanced (customized) services; corporate spin-off (Rule 6).	Global	2	40
Research, somewhat older age, long-lasting innovation projects (Rule 7)[b].	Global	8	405
Foreign subsidiaries, including manufacturing (not based on a rule).	Global	3	±800[c]
Totals (% share)	Local	14 (52%)	115 (8%)
	Global	13 (48%)	1.245 (92%)

[a] Excluded are pharmaceutical companies, medical systems and consultancy
[b] Rule 7 and Rule 8 cover the same segment
[c] The share of biotechnology knowledge workers in manufacturing (Centocor) is estimated at 70%
Source: Adapted from van Geenhuizen (2007)

need for global knowledge. A quick shift to global knowledge networks by research companies also follows from the fact that in the Leiden cluster and in a larger area, a strong basis of leading domestic pharmaceutical and biotechnology companies that can push young companies further towards the market was missing until recently (currently *DSM-Biologicals* attempts to perform this role). The previous findings on very young companies comply with the biotechnology industry in France, where Mytelka (2004) observed that second generation companies, mostly not older than two years, moved to be engaged in relatively intense partnering with activity and partnerships abroad. By contrast, Leiden-based *Octoplus* (established in 1995) represents somewhat older research companies that employ mainly global relationships. Thus, *Octoplus* has major agreements with Singapore-based *SingVax*, US-based *Surmodics* and *Biolex Therapeutics*, and Germany-based *InAmed*, aside from collaboration with the Leiden research hospital and medical school. The latest development among the somewhat larger Leiden-based companies is the opening of an office or facility in the US, as is true for *Crucell* and *Octoplus*.

The pattern is clearly different for service companies that supply rather standardized services and focus on the regional (national) market. Their major knowledge sources tend to be local/regional customers, networks of the entrepreneur and knowledge institutes, and national suppliers of measurement/testing equipment. Thus, Leiden-based *Baseclear* relies mostly on the local cluster and the remaining country in knowledge interaction, particularly on its local personal network, customers and university.

Attention is now focused on a small numerical estimate of the extent to which global knowledge networking couples with delocalizing of networks. A quasi-experimental design, in which two pairs of objects that are identical in all other relevant characteristics can be compared (Table 7) is used. These relevant characteristics were, of course, the local environment of a cluster, but also age (or lifecycle); the latter because of our

Table 7 Biotechnology companies employing local/regional and global knowledge

Biotech Companies: Local (L) versus Global (G) knowledge users	Added sum of scores in *current* situation	Reduction[a]	Added sum of scores in *changing* situation	Reduction[a]
Aged around 10 years				
L1–G1	17–13	76	28–13	46
L1–G4	17–12	71	28–10	36
Aged around 5 years				
L2–G2	19–15	79	24–8	33
L2–G3	19–19	100	24–32	133
L2–G5	19–13	68	24–20	83

[a] Reduction of connectedness as a percentage of connectedness of local networking companies (= 100%)
N (companies): 7

previous outcomes and the general believe that as companies mature they reduce their degree of local connectedness. The only difference between companies in a pair is a differently shaped knowledge network. It appears that global knowledge networking couples with a weaker local connectedness, except for one company type, i.e. the previously mentioned young research companies that are functionally linked to the knowledge organisation (origin). The reduction in the current situation ranges from 68 to 79%. The reduction in the changing situation is larger, but shows also a larger variety, i.e. from 33 to 83%. The strongest reduction in the changing situation (33%) is true for a young research company after being acquired by a foreign company, a type of development also observed by DeMartino et al. (2006). In conclusion, our experiment suggests some reduction of local connectedness in the current situation and a somewhat stronger - but also more differentiated—reduction if changes are taken into account.

7 Conclusion

The role of localized knowledge and learning as an advantage of clustered locations is increasingly being questioned. Some empirical studies indicate that the influence of local proximity in knowledge networks stretches over larger distances than in previous times, while others (mostly in biotechnology) produce a mixed evidence suggesting that local and global knowledge networks co-exist. This study has connected with the latter evidence and sought to fill a gap in understanding of factors that contribute to shaping local and global knowledge networks, other than local proximity. By adopting an entrepreneurial perspective, it has attempted to identify relevant strategy and capability factors on the company level. Our results of a case study of urban innovators in the Netherlands suggested a coexistence of predominantly local/regional networks and global networks. The former mainly on the basis of a regional focus in the overall strategy and the latter mainly on the basis of network capabilities derived from the parent company or a competitive strategy driven by high innovation intensity.

In a next step, we applied the previous findings (as rules from rough set analysis) to a population of a biotechnology cluster, and this learning experiment also indicated a situation of coexistence of local and global knowledge networking. Further, the results provide evidence that the lifecycle of companies is important in the configuration and reconfiguration of knowledge networks. Research companies emerge as being strongly embedded in local networks but, for various reasons, need to quickly shift to knowledge partnering abroad. At the same time, service companies providing relatively standardized tests and measurement tend to remain mainly involved in local/regional knowledge networks.

The study has also taken the subject further by addressing dynamics in local connectedness of the companies concerned. The tentative results of learning experiments covering various urban companies and companies in a specific biotechnology cluster, suggested that global knowledge networking enhances delocalizing of networks to a limited extent. Aside from a relatively strong evidence for delocalizing of supplier relations and personal relations of the entrepreneur, some contradictory trends could be observed, indicating that, overall, delocalizing of networks is not pre-dominating and developments are rather differentiated. The differentiation occurs along the lines of the lifecycle progression of companies and the latter's strategies. Accordingly, among companies that employ mainly global knowledge relationships only limited evidence was found of what Hendry et al. (2000) and Hendry and Brown (2006) observed in the optoelectronics industry, i.e. a trend of proximity without interaction or intimacy.

This study is clearly an early, exploratory research using various small learning experiments. The outcomes call for a further elaboration and rigorous testing. This holds for relatively strong results concerning determinants of knowledge networks: spatial focus in the overall strategy, network capabilities from parent companies and innovation intensity. It also holds for the differentiated pattern of weakening of local connectedness. The latter is important from a policy perspective, because cluster policies may be designed to improve particular assets in the cluster and increase local connectedness in various ways.

Despite the interesting results, this study has limitations following from choices made in the design of the study and in the modelling. The observed trends refer only to relatively young companies. With regard to older companies, the trend of delocalizing may be stronger, particularly if these companies have moved research or production activity in own sites abroad. Also, as a first experiment, a one way causal relation was assumed between globalization and local connectedness, whereas a two-way model or circularity may be more realistic. Here are two additional paths for future research. Furthermore, there is a methodological challenge. The prediction accuracy of the current outcomes of rough set analysis was assumed to be around 75% based on tests in other studies, but it could not be tested in the frame of this study. Drawing selected samples—to further improve and test prediction accuracy—together with random samples in a smart (pooled) structure would enable randomizing the rough set rules on knowledge networks and allow statistical generalization of all the results within the selected spatial context. Finally, this study contributes just one small piece to a large jigsaw, named clusters. Like many other pieces, ours may not fully match. In research to date, the core difficulty in cluster research is defining and measuring clusters, local relationships and environments, in a precise way

(Martin and Sunley 2002). The study took a pragmatic approach by using the urban region as the spatial entity, not a cluster delineated on the basis of a precise and consistent measurement. This calls for improvement in next research steps.

Acknowledgment This study has benefited from funding by the Netherlands Organisation for Scientific Research (project number 014-43-616-P) and by the Delft Centre of Sustainable Urban Areas (Delft University of Technology, The Netherlands).

Annex 1

Prediction accuracy of decision rules as tested in various studies

Author	Application area	Range (%)	Average (%)
Company studies			
Slowinsky et al. (1997)	Company acquisition	75.0–68.3	71.7
Dimitras et al. (1999)	Company failure	98.8–50.0	74.4
Sanchis et al. (2006)	Company failure	80.6–65.9	74.6
Other studies			
Goh and Law (2003)	Travel demand	100–77.8	87.2
Soetanto and van Geenhuizen (2007)	Incubator development	84.0–61.0	73

The studies differ in number of tests and independence of the test samples vis-a-vis the base sample

Annex 2

Knowledge networking and local connectedness

	Category 1: Local knowledge networking	Category 2: Global knowledge networking	Totals
Strengthening of local connectedness (LC)	7	3 (of which all face a strong reinforcing of LC)	10
Weakening of local connectedness (LC)	2	9 (of which some face a strong weakening of LC)	11
Totals	9	12	21

References

Acs ZJ (2002) Innovation and the growth of cities. Edward Elgar, London

Andersson S, Wictor I (2003) Innovative internationalisation in new firms: born globals—the Swedish Case. J Int Entrepreneurship 1:249–276

Audretsch DB (1998) Agglomeration and the location of innovative activity. Oxf Rev Econ Policy 14:18–29

Audretsch D (2001) The Role of small firms in US biotechnology clusters. Small Bus Econ 17:3–15

Bagchi-Sen S, Lawton Smith H, Hall L (2004) The US biotechnology industry: industry dynamics and policy. Environ Planning C: Government Policy 22:199–216

Barney JB (1991) Firm resources and Sustained competitive advantage. J Manage 17(1):99–120
Bathelt H, Malmberg A, Maskell P (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Progr Hum Geogr 28:31–56
Best M (2001) The new competitive advantage. Oxford University Press, Oxford
Biopartner (2002–2005) The Netherlands Life Sciences Sector Report 2002–2005 (Ede: Biopartner)
Borgatti SP, Foster P (2003) The network paradigm in organizational research. A review and typology. J Manage 29:991–1013
Boschma RA (2005) Proximity and innovation: a critical assessment. Reg Stud 39(1):61–74
Britton JNH (2004) High technology localization and extra-regional networks. Entrepreneurship Reg Dev 16:369–390
Brush CG, Greene PG, Hart MM, Haller HS (2001) From initial idea to unique advantage; the entrepreneurial challenge to construct a resource base. Acad Manage Executive 15:64–78
Bureau Louter (2003) Economic Hot Spots in the Netherlands (in Dutch) (The Hague: Ministry of Economic Affairs)
Chetty S, Wilson HIM (2003) Collaborating with competitors to acquire resources. Int Bus Rev 12:61–81
Capello R, Faggian A (2005) Collective learning and relational capital in local innovation processes. Reg Stud 39(1):75–87
Coenen L, Moodysson J, Asheim B (2004) Nodes, networks and proximities: on the knowledge dynamics of the medicon valley biotech cluster. Eur Plan Stud 12(7):1003–1018
Cohen W, Levinthal D (1990) Absorptive capacity: a new perspective on learning and innovation. Admin Sci Q 35:128–152
Cooke P (2004) The molecular biotechnology revolution and the rise of bioscience megacentres in North America and Europe. Environ Plan C: Government Policy 22:161–177
Cooke P (2005) Rational drug design, the knowledge value chain and bioscience megacentres. Camb J Econ 29:325–341
Cumbers A, Mackinnon D, Chapman K (2003) Innovation, collaboration, and learning in regional clusters: a study of SMEs in the Aberdeen oil complex. Environ Plan A 35:1689–1706
Dana LP (2001) Introduction networks, internationalization and policy. Small Bus Econ 16:57–62
Dankbaar B (2004) Embeddedness, context, proximity and control. Eur Plan Stud 12(50):691–701
Dimitras AI, Slowinski R, Susmaga R, Zapounidis C (1999) Business failure prediction using rough sets. Eur J Oper Res 114:263–280
Dosi G (1997) Opportunities, incentives and the collective patterns of technological change. Econ J 107:1530–1547
Feldman M (1994) The geography of innovation. Kluwer, Dordrecht
Feldman M (2000) Location and innovation: the new economic geography of innovation, spillovers, and agglomeration. In: Clark G, Feldman M, Gertler M (eds) The Oxford handbook of economic geography. Oxford University Press, Oxford pp 373–394
Florida R (2002) The rise of the creative class, and how it is transforming work, leisure, community and everyday life. Basic Books, New York
van Geenhuizen M (2003) How can we reap the fruits of academic research in biotechnology? In search of critical success factors in policies for new-firm formation. Environ Plan C: Government Policy 21:139–155
van Geenhuizen M (2005) ICT, location dynamics and the future of cities. Delft/The Hague: Delft University of Technology, Faculty of Technology, Policy and Management/Netherlands Science Foundation. http://www.nwo.nl/nwohome.nsf
van Geenhuizen M (2007) Knowledge networks of young innovators in the urban economy. Entrepreneurship Reg Dev (forthcoming)
van Geenhuizen M, Nijkamp P (2007) Cities and footlooseness: in search of place-bound companies and effective location. Environ Plan C Government Policy (in press)
van Geenhuizen M, Reyes-Gonzalez L (2007) Does a clustered location matter for high-technology companies' performance? The case of biotechnology in the Netherlands. Technol Forecast Soc Change (in press)
Gertler M (2003) Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there). J Econ Geogr 3:75–99
Gertler M, Levitte YM (2005) Local Nodes in global networks: the geography of knowledge flows in biotechnology innovation. Ind Innovat 12(4):487–507

Granovetter M (1985) Economic action and social structure: the problem of embeddedness. Am J Sociol 91(3):481–510
Goh C, Law R (2003) Incorporating the rough sets theory into travel demand analysis. Tourism Manage 24:511–517
Guiliani E, Bell M (2005) The micro-determinants of meso-level learning and innovation: evidence from a Chilean wine cluster. Res Policy 34(1):47–68
Hendry C, Brown J (2006) Dynamics of clustering and performance in the UK opto-electronics industry. Reg Stud 40:707–725
Hendry C, Brown J, Defillippi R (2000) Regional clustering of high technology-based firms: opto-electronics in three countries. Reg Stud 34:129–144
Hoang H, Antoncic B (2003) Network-based research in entrepreneurship: a critical review. J Bus Ventur 17:1–23
Johnson DKN, Siripong N, Brown AS (2006) The demise of distance? The declining role of physical proximity for knowledge transmission. Growth Change 37(1):19–33
Lawton-Smith H (2004) The biotechnology industry in Oxfordshire: enterprise and innovation. Eur Plan Stud 12:986–1001
Lechner C, Dowling M (2003) Firm networks: external relationships as sources for the growth and competitiveness of entrepreneurial firms. Entrepreneurship Reg Dev 15:1–26
Lockett A, Thompson S (2001) Resource-based view and economics. J Manage 27:723–755
Madsen T-K, Servais P (1997) The internationalisation of born globals: an evolutionary process? Int Bus Rev 6(6):561–583
Manguematin V, Lemarie S, Boissin JP, Catherine D, Corolleur F, Cororini R, Trommeter M (2003) development of SMEs and heterogeneity of trajectories: the case of biotechnology in France. Res Policy 32:621–638
DeMartino R, McHardy Reid D, Zygliodopolous SC (2006) Balancing localization and globalization: exploring the impact of firm internationalization on a regional cluster. Entrepreneurship Reg Dev 18:1–24
Martins LL, Gilson LL, Travis Maynard M (2004) Virtual teams: what do we know and where do we go from here? J Manage 30(6):805–835
Martin R, Sunley P (2002) Deconstructing clusters. J Econ Geogr 3:1–15
de Martino R, McHardy Reid D, Zygliodopoulos S (2006) Balancing localization and globalization: exploring the impact of firm internationalization on a regional cluster. Entrepreneurship Reg Dev 18:1–24
Maskell P, Malmberg A (1999) Localised learning and industrial competitiveness. Camb J Econ 25:167–185
Masurel E, Nijkamp P, Vidigni G (2004) Breeding places for ethnic entrepreneurs: a comparative marketing approach. Entrepreneurship Reg Dev 16:77–86
Mytelka L (2004) Clustering, long-distance partnership and the SME: a study of the French biotechnology sector. Int J Technol Manage 27(8):791–808
McDougall P, Shane S, Oviatt BM (1994) Explaining the formation of international new ventures. J Bus Ventur 9:469–487
McKelvey M, Alm H, Riccaboni M (2004) Does location matter? Knowledge collaboration in the Swedish biotechnology-pharmaceutical sector. Working paper ESSY. Chalmers University, Gothenburg
MEA (Ministry of Economic Affairs) (2000) Action Plan Life Sciences 2000–2004. Ministry of Economic Affairs, The Hague
Nooteboom B (2000) Learning and innovation in organisations and economies. Oxford University Press, Oxford
Pawlak Z (1991) Rough sets. Kluwer, Dordrecht
Pawlak Z (2001) AI and intelligent industrial application: the rough set perspective. Cybern Syst Int J 31:227–252
Polkowski L, Skowron A (1998) (eds) Rough set in knowledge discovery. Springer, Berlin
Ponds R, van Oort F (2006) Knowledge hubs in the Netherlands. Spatial patterns of research cooperation (in Dutch). NAI Publishers/Spatial Planning Bureau, Rotterdam/The Hague
Porter ME (2000) Locations, clusters, and company strategy. In: Clark GL, Feldman M, Gertler M (eds) The Oxford handbook of economic geography. Oxford University Press, Oxford, pp 253–274
Rialp A, Rialp J, Knight GA (2005) The phenomenon of early internationalizing firms: what do we know after a decade (1993–2003) of scientific inquiry? Int Bus Rev 14(2):147–166
Roijakkers N, Hagedoorn J (2006) Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: trends, patterns, and networks. Res Policy 32:431–446

Rosenthal SS, Strange WC (2001) The determinants of agglomeration. J Urban Econ 50:191–229
Sanchis A, Segovia MJ, Gil JA, Heras A, Vilar JL (2006) Rough sets and the role of the monetary policy in financial stability (macroeconomic problem) and the prediction of insolvency in insurance sector (microeconomic problem). Eur J Oper Res (in press)
Simmie J (2003) Innovation and urban regions as national and international nodes for the transfer and sharing of knowledge. Reg Stud 37:607–620
Słowiński R, Zopounidis C, Dimitras AI (1997) Prediction of company acquisition in Greece by means of the rough set approach. Eur J Oper Res 100:1–15
Soetanto DP, van Geenhuizen M (2007) Technology incubators and knowledge networks. a rough set approach in comparative project analysis. Environ Plan B Plan Des (in press)
Storper M, Scott A (1995) The wealth of regions: market forces and policy imperatives in local and global context. Futures 27:505–526
Uzzi B (1997) Social structures and competition in interfirm networks: paradox of embeddedness. Admin Sci Q 42(1):37–69
Warren RH, Johnson JA, Huang GH (2004) Application of rough sets to environmental engineering models. In: Peters JF, Skowron A (eds) Transactions on rough sets I, Lecture Notes in Computer Science. Springer, Berlin, vol. 3100, pp 356–374
Wolfe D, Gertler M (2004) Clusters from the inside out: local dynamics and global linkages. Urban Stud 41(5/6):1071–1094
Yin RK (1994) Case study research. Sage, Thousands Oaks