How to investigate knowledge networks in space? Social network analysis concept

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Abstract

This paper gives both theoretical insights in the concepts of knowledge networks and practical examination of social networks analysis (SNA) methodology. Knowledge networks consist of nodes (learning and teaching nodes - knowledge stocks) and connections among them (knowledge flows). Using UCINET, PAJEK and NETDRAW software gives the opportunity to introduce quantitative analysis of social networks with graphic interpretation. We explore the knowledge flows in science, based on the citation analysis and study the structure (in terms of density, clustering and centralisation) of these networks through network analysis techniques and test the influence of geographical distance. The architecture of the network is further explored to reveal intense relationships as well as the core members of a network.

Key words: network, knowledge flows, citations, network analysis

1 Introduction

Knowledge is usually attributed to occur in two forms - tacit and codified. Tacit knowledge is knowledge that people carry in their minds and is, therefore, difficult to access. As Polanyi's famous aphorism stated *"We know more that we can tell"*. On the other hand codified knowledge is by definition part of knowledge which is easily accessible and can be transmitted through information technologies and infrastructures over long distances and across organisational boundaries. There are several approaches how to study knowledge stocks and flows in the economy and society. First one of the two fundamental origins is based on the recognition that knowledge is **embedded in organisations** (usually studied at the firm level). This knowledge is embedded and carried through multiple entities including organizational culture and identity, policies, routines, documents, systems, and employees. Originating from the strategic management literature (e.g. CONNER 1991), this perspective builds upon and extends the resource-based view of a company (initially promoted by PENROSE in 1959) and later expanded by others. The concept of the theoretical assumptions of the role of knowledge in a company was summarised by GRANT R. M. (1996). SPENDER J. C. (1996) when

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dealing with the integration of knowledge, other important authors are KOGUT B. (2000), ZANDER U. (1992) and NONAKA, TAKEUCHI (1995). Second, knowledge has been found to be **spatially concentrated.** Attempts to understand the dynamics of regional growth and development have led to two sets of ideas coming to prominence: the concept of systems of innovation and the role of knowledge and learning. The basis for the concept of innovation systems were the scientific works of LUNDVALL (1992) and NELSON (1993), later applied on regional and local systems (BRACZYK et. al., 1997; COOKE et. al., 1998). Those regional systems are variously called -clusters, regional production complexes, productive systems, regional systems, milieus, and local systems (ACS et. al, 1996; ASHEIM a DUNFORD, 1997; COOKE, 1996; FESER, 1998; PORTER, 1998, ROSENFELD, 2002; STEINER, 1998). **The network approach** stresses that knowledge is considered to be collective good (ANTONIELLI, 2007) usually embedded in networks. According to the development of the knowledge network we will observe cumulative and composite trajectories. In practice a company's internal capacity for R&D is no longer sufficient for technological competitiveness (MALECKI E. J., CHESHIRE P. C, 2004). Due to higher diversity and specialisation of knowledge, the need of companies to associate and cooperate with other firms and institutions is intensifying. We may observe different patterns of knowledge stocks and knowledge flows in the network within and between the groups of individuals that are identified. In-deep research within this approach is based on the social network analysis, which suggests that knowledge processes are determined, at least in part, by relationship patterns. Initially, the analysis focused on the connection between micro-level interactions and macro-level patterns of the network. In our paper we will focus on scientific knowledge, which is usually strongly embodied, it means that it is strongly bounded with individuals or organisations. In fact, even when it takes the form of a highly codified expression, it has high levels of tacitness and requires high levels of competence to be generated, transmitted and communicated (ANTONIELLI, 2007). ZITT et al. (2000) found that geographic links are strong in science.

2 Research approach

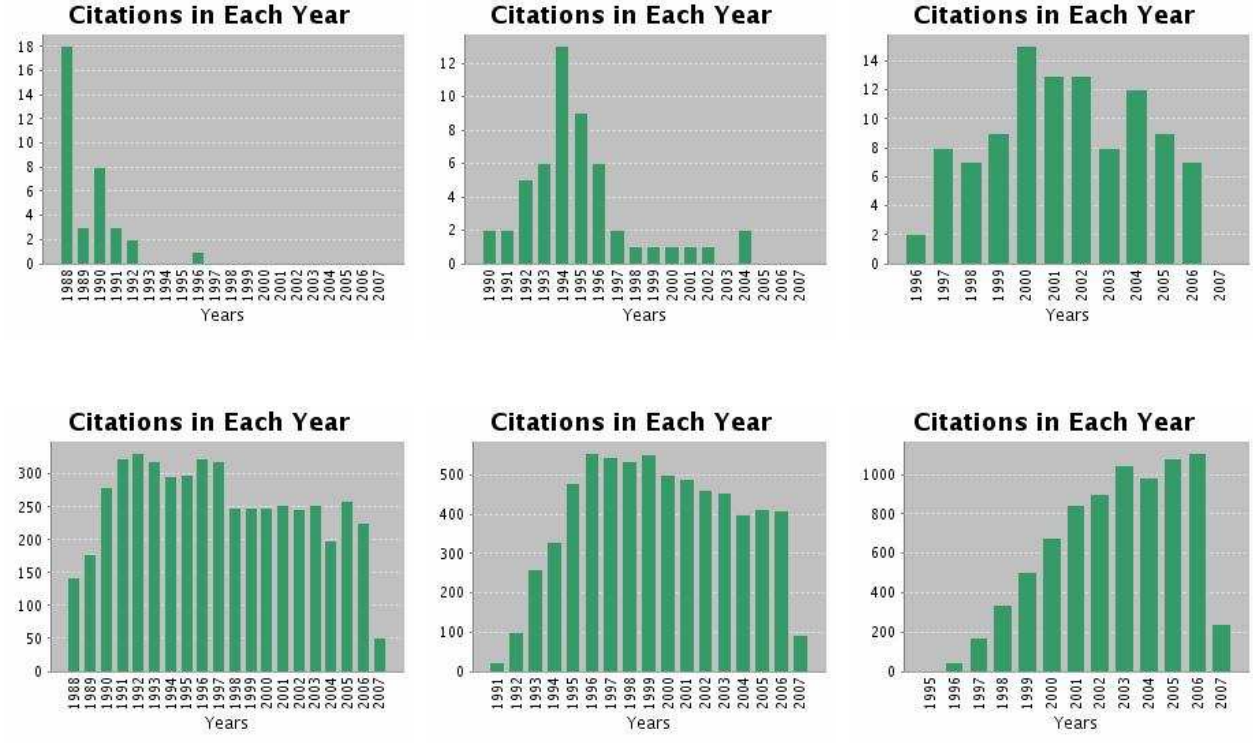
This paper is our entry study of the knowledge networks using the social network methodology. The main objective of the paper is to test and evaluate network analysis for studying knowledge flows in space. By mapping the co-authorship and citations networks in *Ekonomicky casopis* from the electronic database Web of Knowledge (SCI Thomson on citations) containing all relevant papers produced in economic science for 10-year period (1991-98), we infer the dynamic and the structural mechanisms that govern the evolution and topology of this network. The social group of economic scientists in Slovakia I personally belong to, is appropriate study object and it gives an opportunity to put my own perceptions and interpretations on the results. The main question of this paper is: *To what extent are knowledge flows in networks determined by spatial and cognitive distance.*

There are several ways how to cope with the factor of space in the network. We decided not to measure spatial/geographical distance by geodesic distance of nodes in the network, rather than we assigned nodes according their locality (city). Studies of network architecture find that real networks are clustered, meaning that they possess local communities in which a higher than average number of people know one another. A general feature of these studies is that they are restricted to rather small systems, and often view networks as static graphs, whose nodes are individuals and links represent various quantifiable social interactions (BARABASI et. al, 2002, p. 591)

General development of the economic science in Slovakia

What is clear, however, is that the radical transformation during the 1990s influenced not only the behaviour of the economic system itself but modified existing knowledge value chains as well. Especially scientific fields as law or economy, which were based on different ideology undergone dramatic changes. Following figure shows us an example of discontinuity of knowledge from years before 1989. Using data from SCI Thomson on citations in *Ekonomicky casopis* and *Journal of Economic Literature* (as a benchmark) in three different periods we may observe a "life cycle" of knowledge. The first graph in upper row represents cumulative counts of citations from *Ekonomicky casopis* within the period 1988 -1993. Number of citations dropped sharply to zero, that could be explained by rapid change of knowledge base in economic science (from planning economics towards the free market economics) and by the start with new knowledge trajectories. The second argument could be that the *"quality"* of knowledge (this is obvious in the second graph) differs; papers in that time were based more on the description of the transformation process, rather than presenting results of the more fundamental research. Only the last graph representing the citations on the papers from the period 1996 - 2000 we may observe kind of longer "sustainability" of knowledge. It means we assume that this is the result of new knowledge trajectories in economic science in Slovakia. However comparing with the citations on JEL the period it is still very small amplitude. Journal of Economic Literature shows more cumulative citations processes where the new knowledge is a subject to further development.

Figure 1: Life cycle of knowledge (EC vs. JEL)

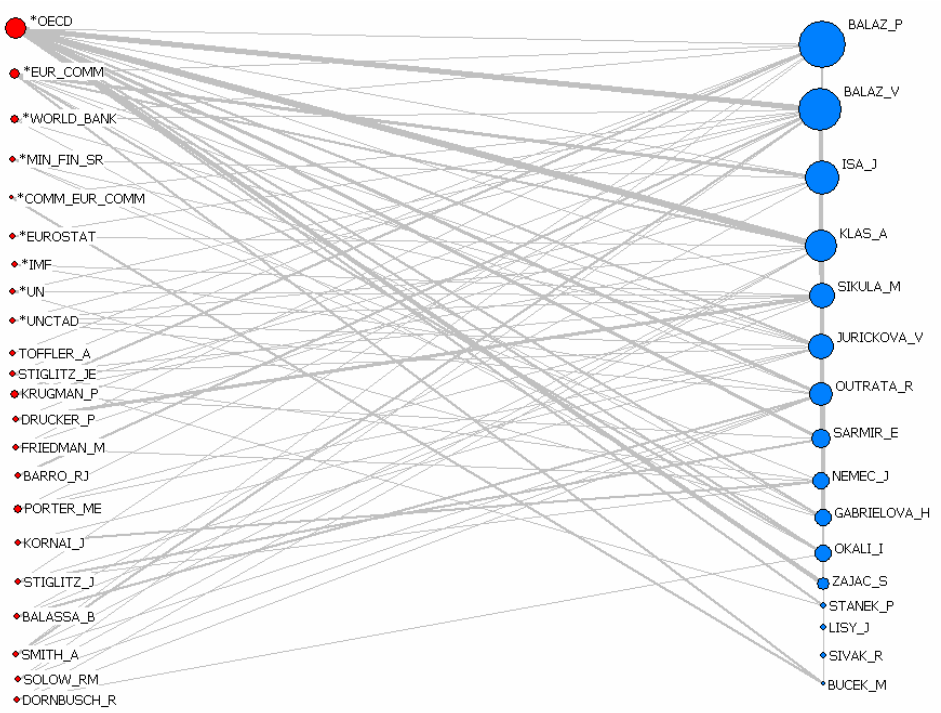


Network analysis of the economic science in Slovakia

Usually in the scientometric analysis there are two fundamental techniques how to study the flows of knowledge in the networks - co-authorship networks (e.g. WAGNER, LEYDESDORFF, 2003) and citations networks (e.g. BARABASI et. al, 2002). Co-authorship network may be described as the network of tacit knowledge. Units in a collaboration network are usually individuals or institutions. Two units are related if they produced a joint work, in this case we state that co-operation in the research is necessary for flow of tacit knowledge. A famous example of collaboration network is The Erdos Number Project (Erdos.net). The other approach is the citation networks. Citations can be viewed as quantitative measures of the use of the listed bibliography, regardless of the qualitative degree of reliance on them. Citations network are

oriented graphs. It means that we should wok with arcs and in our analysis will distinguish in and out links. When going into the more detailed study of the knowledge processes in networks we started with investigating the global - national knowledge interactions. Traditionally, spatial proximity is considered as important, because knowledge is generated through activities of local actors. On the other hand, universities and research centres often play role of gateway to world of global knowledge, and are the place where global and local knowledge interplay. Analysing the references of the papers in the period 1997 - 2006 we were focusing on tracing the most influential knowledge sources (authors). The network consists of 1000 vertices with 2114 ties. This is an oriented network and according the system of collecting data it is a network *ofegonets.* According the bibliographical system authors could be either collective (institutions) or individual. In the next figure you can see that most influential sources were collective authors - institutions like OECD (87) and European Commission (32) and World Bank (21). Most influential international individual authors were Krugman, Toffler, Stiglitz, Drucker and Friedman.

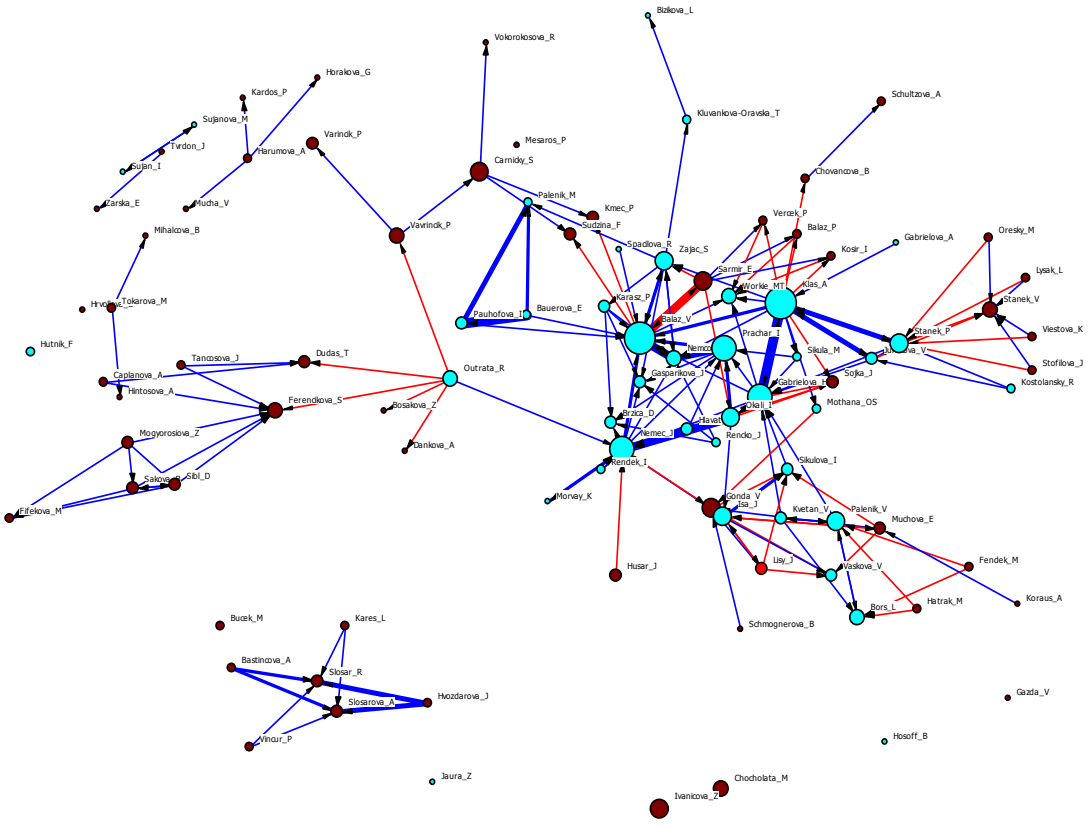
Figure 2: Global - national knowledge interactions (1997 - 2006)



From the network perspective, we are dealing with the network with the 0.0015 **density** (standard deviation = 0.0389) which indicate that this network is rather fragmented and weakly interconnected, however we may assume several strong components. We may apply several techniques for identifying subgroups in the network. Divisions of actors into groups and sub-structures can be a very important aspect of social structure, the consistency of large structures can be built up out of small and tight components. Using the **clique** technique we measured interdependencies among authors. Clique is a sub-set of a network in which the actors are more closely and intensely tied to one another than they are to other members of the network. By defining level of clique at 5, it means we want to identify groups of 5 authors, we have identified 11 cliques. Seven out of eleven cliques are based on the collective author OECD or EC. In this case we did not have the data on the location of authors therefore we did not carry out more detailed analysis.

The second example of the citation network we studied is the network of citations on papers published in the *Ekonomicky casopis* within the period 1997 - 2006. This network consists from 169 nodes linked by 342 ties (citations among authors). The overall density of the citation network is (0.0103), it could be considered as rather sparse. It means that knowledge is obviously significantly bounded in small group of authors with limited diffusion to the rest of network. We may expect small core of interconnected authors and large periphery parts of more isolated groups of authors.

Figure 3: Citation networks in economics 1997 - 2006



Defining the minimum number of actors in a clique as 4[1] we have identified 11 subgroups. All but one of identified **cliques** is located in the Bratislava region and 6 of them are mono-organisational (Slovak Academy of Science (SAV) and University of Economics (EU)). Ten cliques are located in Bratislava, intraregional clique appeared only once in the case Bratislava - Zilina. This suggests that knowledge clusters will be usually monoregional where both cognitive distance and spatial proximity plays crucial role.

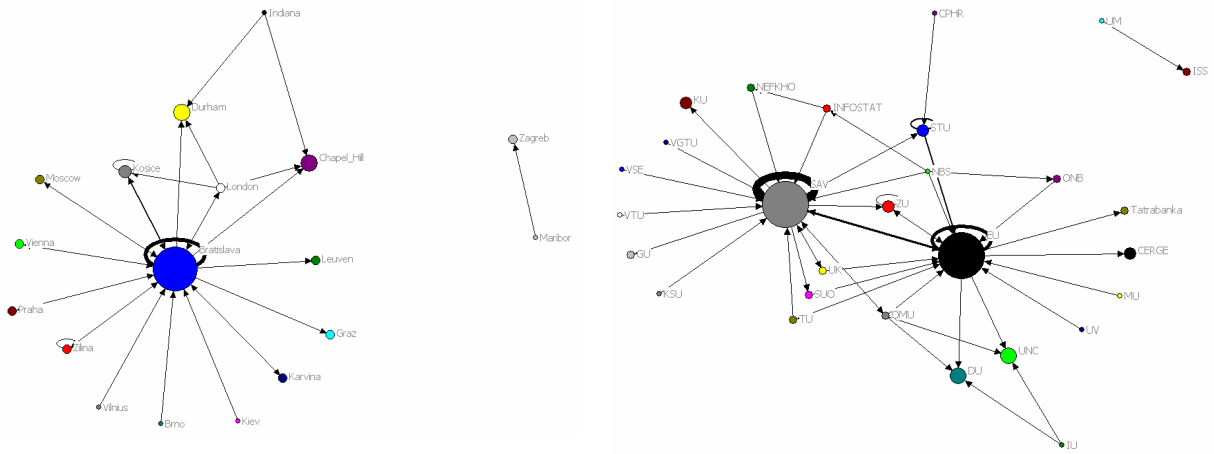
Another measure to identify sub-groups in the network is the **k-core.** A k-core is a maximal group of actors, all of whom are connected to some (k) number of other members of the group. If an actor has ties to a sufficient number of members of a group, they may feel tied to that group ~ even if they don't know many, or even most members. Intra organisation links in the graph are showed as blue and inter organisational are represented by red lines.

First we can explore the structure of the network according the centrality measures. Apart from measures in the global reference network, introduced in the first part of this paper, we will introduce different centrality measures. **Betweenness** centrality views an actor as being in a favoured position to the extent that the actor falls on the geodesic paths between other pairs of actors in the network. That is, the more people depend on make connections with other people, the more power the actor has. In our case the highest dirBetweenes (value 1124,4) of actor Gabrielova_H (SAV, BA) is suggesting that the node is a knowledge gate-opener in the network. When taking a cognitive proximity into consideration, it means that this author connects different subsets of knowledge stocks. In the knowledge network this is can be explained by bringing new composite knowledge in to the accustomed knowledge.

By shrinking the network and grouping authors according their affiliation to organisation or region we studied knowledge flows from different perspective. This reduction was realised in PAJEK software, which is usually used for analysis of large networks. The question we explored was: to what extent are knowledge flows embedded in organisations? and which patterns of spatial knowledge flows can we observe? The number of cited authors from BA region in the total population in the data set is 64%. However, as showed in following figures most of the knowledge flows are intraregional (represented by the loops in the graph) - totally 85% of all citations were coming from and at the same time going to the Bratislava region.

[1] This is highest possible number (representing minimum number of actors) by using which we can identify at least one clique in our network.

Figure 4: Citation networks - Intra/inter organisational and intra/inter regional flows



Centralisation of knowledge flows within the network could be documented by share of intraorganisational citations. In our case not less than 52% of all citations were intraorganisational. Two largest economic institutions - University of Economics (EU) and Slovak Academy of Sciences (SAV, Economic institute and Institute of Forecasting) showed significant degree of self-citations (loops in the graph), EU 57% and SAV 75%. Nonetheless quite balanced number of bilateral citations (25 or 27) between EU and SAV emerged in the graph. From this point of view the flow of knowledge in the economic science is rather closed system.

3 Conclusions

This paper is our first approach to the methodological issues of howl to study the knowledge flows using the basic network principle. By mapping the electronic database containing the Slovak economic journal in 10-year period (1997-2006), we infer the structural mechanisms that govern the structure of this complex system. Three complementary approaches allow us to obtain a detailed characterization. First, microstructure of the network was identified by the network centrality measurements, which allow us to identify crucial authors in the network. Indegree centrality and betweeness centrality shows authors with high reputation in the network. By identifying substructures with k-core and clique techniques we could look into the structures of the network. Shrinking the network and grouping authors according their affiliation to organisation or region allowed us to analyse regional and organisational flows.

Relations between individuals are not static; 'embedded relational dynamics' would be a better description. From the spatial perspective, knowledge flows in economics could be described as cumulative and to some extent closed process centralised in the Bratislava region with only limited knowledge spill-overs in space. Even though codified knowledge are almost perfect mobile in space, knowledge dynamics seems to be predominantly local cumulative process. One of the future dimensions of the knowledge network studies would be to trace the time dimension

of the knowledge dynamics. Introducing time dimension in the flows of the knowledge (BARABASI et. al, 2002, p. 591) will help us to better understand how to cope with the peripherality of the network components. Again we will try to introduce the importance of spatial proximity and cognitive proximity in this process.

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References

1. HANNEMAN et. al. 2005. Introduction to social network methods. Riverside, CA: University of California, Riverside (published in digital form at http://faculty.ucr.edu/~hanneman/)
2. de NOOY, W., MRVAR, A, BATAGELJ, A, 2005. Exploratory Social Network Analysis with Pajek, Oxford University Press, Cambridge, ISBN 978-0-521-60262-4
3. BORGATTI, S.P., EVERETT, M.G. and FREEMAN, L.C. 2002. Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.
4. BORGATTI, S.P. 2002. NetDraw: Graph Visualization Software. Harvard: Analytic Technologies
5. BATAGELJ V., MRVAR, A. 2007. Pajek - Program for Analysis and Visualization of Large Networks, University of Ljubljana, http://vlado.fmf.uni-li.si/pub/networks/paiek/
6. WAGNER, C, S., LEYDESDORFF, L. 2003. Mapping Global Science Using International Co-authorships: A Comparison of 1990 and 2000, Amsterdam School of Communications Research (ASCoR), University of Amsterdam
7. GRABHER, G. 2004. Trading routes, bypasses, and risky intersections: Mapping the travels of 'networks' between economic sociology and economic geography, SECONS Discussion Forum Socio -Economics of Space University of Bonn
8. ACS et. al. (1996). Local systems of innovations: In search of an enabling strategy. In Howitt, P. ed. The implications of knowledge based growth for micro economic policies, University of Calgary Press, Calgary, s. 339 - 359
9. ASHEIM, B., DUNFORD, M. (1997). Regional Futures. Regional Studies, 31, 445 - 455
10. BOEKEMA, F. et. al. (2000). Knowledge, innovation and economic growth: The theory and practice of learning regions, Edvard Elgar, Cheltenham
11. ll.BRACZYK et. al. (1997). Regional innovation systems: The role of governance in globalised world, UCL Press, London
12. CONNER K. R. (1991). Historical Comparison of the Resource-Based Theory and Five Schools of Thought Within Industrial Organization Economics: Do We Have a New Theory of the Firm? Journal of Management (17:1), 1991, pp. 121-154.
13. COOKE, P. (1996). The new wave of regional innovation networks: Analysis, characteristics and strategy, Small Business Economics, 8, 159 - 171
14. COOKE et. al. (1998). Regional systems of innovations: An evolutionary perspective, Environment and Planning, 30, 1563 - 1584
15. COOKE et. al., (2000). The governance of innovation in Europe: Regional perspectives on global competitiveness, Pinter, London

16. COOKE, P. (2002). Knowledge economies: Clusters, learning and competetive advantage, Routledge, London
17. COOKE, P., MORGAN, K. (1998). The Associational Economy, Oxford University Press, Oxford
18. FESER (1998). Old and new theories of industrial clusters, in STE1NER M. edt. (1998). Clusters and regional specialisation: On geography, technology and networks, Pion, London
19. FLORAX, R., J., G., M, PLANE, D., A., (2004). Fifty Years of Regional Science, Berlin, Springer, ISBN 3-540-22361-4
20. FLORIDA, R. (1995). The learning region, Futures 27, s. 527 - 536
21. GRANT R. M. (1996). Toward a Knowledge-Based Theory of the Firm," Strategic Management Journal (17), Winter Special Issue, pp. 109-122
22. KOGUT B. (2000). The Network as Knowledge: Generative Rules and the Emergence of Structure," Strategic Management Journal (21), pp. 405-425
23. KOMNINOS, N. (2002). Intelligent cities: Innovation, knowledge systems and digital spaces, Spon Press, London
24. LUNDVALL, B. (ed) (1992). introduction" in National systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London, Pinter
25. LUNDVALL, B-A., JOHNSON B. (1994) The learning economy, Journal of Industrial Studies 1, **s.23-42**
26. MALECKI E. J., CHESHIRE P. C, (2004). Growth, development and innovation: A look backward and forward in FLORAX, R., J., G., M., PLANE, D., A., (2004). Fifty Years of Regional Science, Berlin, Springer, ISBN 3-540-22361-4
27. NELSON, R.R. (1993). National System of Innovation: A Comparative Study, Oxford, Oxford University Press
28. NONAKA, I., TAKEUCHI, H. (1995). The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation, Oxford University Press, New York
29. PORTER, M. (1998). On competition, Haward Business School Press, Boston
30. ROSENFELD, S. A., (2002). Creating Smart Systems: A Guide to Cluster Strategies in Less Favoured Regions, Regional Technology Strategies, www.rtsinc.org
31. SPENDER, J. C. (1996). Making Knowledge the Basis of a Dynamic Theory of the Firm," Strategic Management Journal (17), Special Issues, pp. 45-62
32. STEINER M. edt. (1998). Clusters and regional specialisation: On geography, technology and networks, Pion, London