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Structure and Strategy within Heterogeneity: Multiple Dimensions of Regional Networking

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ABSTRACT

Clusters are highly differentiated across sectors, regions and countries – both theoretical and empirical approaches therefore have to avoid universalization. Based on recent approaches various forms of network relations and possible contents of interactions of firms connected with knowledge exchange are elaborated. It will be argued that these interactions are distinctively structured, that the diffusion of knowledge is highly selective and strongly dependent on the position of firms within networks and on their absorptive capacity.

By applying network analysis to different dimensions of interactions between firms it is shown that physical linkages within the medium technology cluster under scrutiny are rather weak, that interactions based on different forms of knowledge exchange are denser, and that direct links to the science base seem to be more prominent than long term supplier networks.

Keywords**:** regional networking, knowledge exchange, institutions, network analysis

JEL**:** L29, L62, L64, O39

Structure et stratégie dans l'hétérogénéité : Dimensions multiples des réseaux régionaux

Michael Steiner et Michael Ploder

RESUME

Les groupes sont très différenciés entre secteurs, régions et pays ; les approches théoriques et empiriques doivent donc éviter l'universalisation. S'appuyant sur des approches récentes, diverses formes de relations de réseaux et de contenus possibles d'interactions d'entreprises liées à des échanges d'informations sont élaborées. On pourrait objecter que ces interactions sont structurées de manière distinctive, que la diffusion du savoir est très sélective et dépend fortement de la position des entreprises au sein des réseaux et de leur capacité d'absorption. En appliquant l'analyse de réseau aux différentes dimensions des interactions entre les entreprises, il apparaît que les liens physiques au sein du groupe technologique examiné sont plutôt faibles, que les interactions basées sur différentes formes d'échanges de savoir sont plus denses et que les liens directs avec la base scientifique semblent plus éminents que les réseaux de fournisseurs à long terme.

Mots-clés : réseautage régional, échanges de savoir, institutions, analyse de réseau

JEL : L29, L62, L64, O39

Struktur und Strategie innerhalb der Heterogenität: mehrfache Dimensionen der regionalen Netzwerke

Michael Steiner and Michael Ploder

ABSTRACT

Je nach Sektor, Region und Land sind Cluster hochgradig differenziert, weshalb bei den theoretischen und empirischen Ansätzen Verallgemeinerungen vermieden werden müssen. Ausgehend von neueren Ansätzen werden verschiedene Formen von Netzwerkbeziehungen und möglichen Inhalten der Wechselwirkungen zwischen Firmen im Bereich des Wissensaustauschs ausgearbeitet. Es wird argumentiert, dass diese Wechselwirkungen charakteristisch strukturiert sind und dass die Verbreitung von Wissen auf äußerst selektive Weise erfolgt und in hohem Maße von der Position der Firmen innerhalb der Netzwerke sowie von ihrer Absportionskapazität abhängt.

Durch eine Anwendung der Netzwerkanalyse auf verschiedene Dimensionen der Wechselwirkungen zwischen Firmen wird gezeigt, dass die physischen Verknüpfungen innerhalb des untersuchten Clusters der Mitteltechnologie eher schwach ausfallen, dass die auf verschiedenen Formen von Wissensaustausch beruhenden Wechselwirkungen dichter sind und dass direkte Verbindungen zur Wissenschaftsbasis eine prominentere Rolle zu spielen scheinen als langfristige Liefernetzwerke.

Keywords:
Regionale Netzwerke
Wissensaustausch
Institutionen
Netzwerkanalyse

JEL: L29, L62, L64, O39

Estructura y estrategia en la heterogeneidad: dimensiones múltiples del sistema regional de redes

Michael Steiner and Michael Ploder

ABSTRACT

Las aglomeraciones están muy diferenciadas en función de sectores, regiones y países, por lo tanto es necesario evitar una universalización tanto a nivel teórico como empírico. Basándonos en recientes planteamientos, elaboramos distintas formas de las relaciones de redes y los posibles contenidos de las interacciones de empresas conectadas con un intercambio de conocimientos. Sostenemos que estas interacciones están estructuradas de un modo característico, que la divulgación de conocimiento es muy selectivo y depende altamente de la posición de empresas en las redes y de su capacidad absorbente.

Aplicando los análisis de las redes a diferentes dimensiones de interacciones entre las empresas, mostramos que los vínculos físicos en la aglomeración de tecnologías medias bajo escrutinio son bastante débiles, que las interacciones basadas en las diferentes formas de intercambio de conocimientos son más densas y que los vínculos directos para la base científica parecen ser más importantes que las redes de suministradores a largo plazo.

Keywords**:**
Sistema de redes regionales
Intercambio de conocimientos
Instituciones
Análisis de redes

JEL**:** L29, L62, L64, O39

1 Introduction

The debate on clusters, industrial districts and networks of firms has now been around for more than two decades. While earlier contributions to work on industrial agglomerations remain important, the concept of cluster has gained in relevance as a result of a change in the dominant form of production from large scale mass production to flexible specialised producers leading, to the necessity of greater cooperation between firms. The debate has been reinforced by a vast literature (recently e.g. MALMBERG/MASKELL 2002, STORPER and VENABLES 2002, GORDON/McCANN 2005, MALMBERG/POWER 2006) concentrating on the combination of clusters, innovation, and regional development, where innovation is favoured by regionally concentrated interaction of (mostly) small firms mutually exchanging information and creating knowledge in formal and informal ways.

In the search for a common conceptual foundation – or even a unifying theory – and in diverse attempts to find empirical evidence for the role clusters and networks play in a knowledge based economy, several strands of theoretical approaches have been combined: These include analysis of the influence of institutions on human economic behaviour, the role played by knowledge in the creation of wealth, the influence of space and distance for economic decision making, as well as work on the problem of coordinating individual decision making units. Clusters and their networks may now be seen as phenomena that combine the theoretical elements of knowledge, proximity and institutional character.

There has also been a gradual change in perspective regarding the interpretation of clusters, accompanied by a corresponding shift of emphasis in empirical analysis. For example:

- Clusters originally were seen as geographically condensed forms of economic activities and – in the tradition of industrial districts – mostly regarded as material links between firms and/or sectors within given geographical limits. They were often based on value chains or supply links of economic activity. The recent renaissance of interest has focussed more on the immaterial connectivity of clusters emphasizing technological knowledge spillovers and the different forms of learning occurring within and through networks (COOKE/MORGAN 1998, CAPELLO/FAGGIAN 2005, STEINER/HARTMANN 2006).

- Networking has come to be regarded as an important form of innovative activity. This has not only been taken up by regional scientists but also by various strategic management and industrial dynamics approaches to inter-firm cooperation (VONORTAS 2000) and extended to questions of identifying competences and capabilities in strategic management on different levels of economic interaction (FELIN/FOSS 2005).
- The question as to what extent these economic interactions are in need of specific guiding and coordinating institutions is a further new element in the cluster debate. Interactions need institutions (such as markets); yet if the focus is on learning and knowledge, markets alone will not suffice for such forms of interaction and additional institutions will be needed (BÜNSTORF 2003). Clusters may be regarded as coordinating institutions for knowledge sharing , providing a cognitive framework for transforming information into useful knowledge (AUDRETSCH/LEHMANN 2006, STEINER 2006).
- Diverging opinions about the mechanisms and forms of learning and knowledge sharing have thus arisen. Questions highly relevant for research are: What is the geographical extent of clusters, is (geographical) proximity a necessary and/or sufficient condition for the spread of knowledge (RALLET/TORRE 1998); is knowledge spill-over in clusters a pre-dominantly regional phenomenon, or are there also important extra-regional knowledge linkages (BATHELT et al. 2004); are

technological spillovers more or less automatic, or is the process of knowledge diffusion and the spread of innovation consciously driven and dependent on the structural characteristics of clusters, on the 'technological leaders' in a region, or on specific 'gatekeepers' within networks (GIULIANI/BELL 2005).

In terms of empirical analysis, such questions raise several new challenges. In the past, clusters were often defined in terms of geographical concentration of specific sectors or firms. More refined versions used regional input-output tables for the identification of concentrated material linkages and/or bottom-up approaches using firm interviews. The question of knowledge cooperation and diffusion was mostly approached using spatial analysis of patent data and supported by qualitative in-depth interviews and surveys of firms. More recently attempts have been undertaken – especially on the basis of institutional approaches – to use network analysis methods. Such a methodology allows for the mapping and measuring of interactions between different actors; it is hence a helpful instrument in analysing the form and content of relationships of firms within networks and in revealing the system properties of economic and social relations.

This paper will employ such network analysis in order to highlight the structure of knowledge-intensive network relations on the basis of selected interactions between firms in the machinery sector of Styria, a region within Austria. To gain additional insights information resulting from regression analysis and from extensive interviews will be included to support the qualitative analysis of regional cluster dynamics. The aim of the paper therefore – based on recent contributions concerning the role of clusters in the process of knowledge generation and knowledge diffusion – is to gain closer insights into various forms of network relations and into the possible contents of interactions connected with knowledge exchange.

The paper is structured as follows:

Section 2 gives a focussed outline of the conceptual and theoretical approaches in the recent debate and serves as the basis for the identification of relevant questions and the formulation of tentative hypotheses;

Section 3.1 describes the region under scrutiny – Styria, in Austria, whose recent development has led to the need for new firm strategies;

Section 3.2 outlines the data and the methodological approach employed;

Section 3.3 will describe the results of the network analysis in combination with regression analysis and a qualitative interpretation based on extensive interviews;

Section 4 gives a final interpretation and offers conclusions based on research results.

2 Against universalization – yet towards an accepted framework for the analysis and function of networks

As already foreseen by Marshall, variety exists not only between but also within clusters – there is much unobserved heterogeneity. Ranging from strictly defined ideal types to more agnostic theories of spatial clustering (for a useful survey of competing but also overlapping definitions see Belussi (2006) and Paniccia (2006)) a number of constituting criteria have been suggested: spatial proximity, functional inter-linkage, self-awareness among participants and innovativeness/competitiveness (Malmberg/Power 2006) – criteria which are also contained in Cooke/Huggins' (2001) useful definition: "Geographically proximate firms in vertical and horizontal relationships involving a localized enterprise support structure with shared development vision for business growth, based on competition and cooperation in a specific market field". To differentiate this notion of clusters from networks we refer to to NOOTEBOOM (2006, 139) for whom the concept of a network is more general. Accordingly it represents a more general category of inter-firm relations, which does not necessarily entail local embedding, a shared objective, or a specific market. This leads to the consequence that while a cluster is a network, the reverse is not necessarily true.

This implies that the major emphasis in cluster and, more generally, network interpretation has changed from an analysis of forces of agglomeration to forms and contents of organizational learning and knowledge exchange – the original concentration on clusters as mere geographic concentrations of sectors and firms has been converted to a search for institutions for knowledge management and organizational learning, thus more fully emphasizing cluster dynamics (GERTLER/WOLFE 2006). Growth of the knowledge base depends on intended and unintended individual processing of experiences, i.e. 'learning', while the interpretation, transfer and use of experiences is influenced by interaction between individuals and between organizations (COHEN/LEVINTHAL 1989, ANDERSEN 1995, HARTMANN 2004). These insights have shifted the earlier emphasis on material links to the present emphasis on immaterial knowledge flows within clusters and have pointed to the need for connectivity between different agents for knowledge creation and diffusion to take place. This then leads to further questions concerning the degree to which clusters are to be regarded as non-market devices through which firms seek to coordinate their activities with other firms and knowledge-generating institutions. Ongoing learning processes between firms and within clusters stress the importance of institutional arrangements for the generation of knowledge and learning of networks which are not available in the markets (MASKELL/MALMBERG 1999). Since the necessary knowledge may lie outside a firm's traditional core competence interfirm alliances and networks are widely recognized as an important organization form of innovative activity (GAY/DOUSSET 2005).

New forms of evolutionary economic behaviour enter the interpretative framework of economics emphasizing the role of interaction and coordination processes in the economy that have to be taken under conditions of bounded rationality and uncertainty (NELSON/WINTER

1982, SIMON 1991, FOSTER/METCALFE 2001). Vast recent research points to networking capabilities as a key factor in innovation and to the fact that the core of innovative capacity resides in the capacity of various agents and agencies to efficiently combine different pieces of knowledge (for a compilation see RONDE/ HUSSLER 2005). This induces firms to establish a variety of types of interactions and relationships, each of them having different impacts on the knowledge generation and diffusion process. MARIOTTI and DELBRIDGE (2001) speak of the necessity for firms – in the face of knowledge ambiguity, knowledge related barriers, tacitness and knowledge complexity – to engage in the management of a portfolio of ties. Organizations therefore are likely to engage in inter-organizational relations that show a variety of types of ties: These can have quite different dimensions and can be defined according to the character of social relations between actors, the regulation of the relationship, frequency of use, length of the relationship and also of course the nature of information exchange (MARIOTTI/ DELBRIDGE 2001, 13). It is also important to distinguish between both content (i.e. the type of relation) and form (i.e. the social structure of relations) as has been outlined by POWELL/SMITH-DOERR (1994). Mariotti and Delbridge also point in this context to the concept of "modular organization" (SANCHEZ/MAHONEY 1996), i.e. the decomposition of a complex system into loosely-coupled modules in order to permit the integration of specialist knowledge without the actual transfer of knowledge itself – a concept that can be applied to intra-firm structures as well as inter-firm types of cooperation.

As a consequence, from an economic point of view individuals and firms alone are not capable of delivering sufficient amounts and varieties of knowledge. This has to be seen with respect to questions concerning the adequate level and unit of analysis – one of "the most troublesome issues in the social sciences …" (FELIN/FOSS 2006, 1). The question whether the individual or social collectives (firms, networks, regions …) have explanatory primacy is of course an old debate in economics, sociology and the philosophy of science, and has been subsumed under the heading of “methodological individualism” versus “methodological collectivism” (HAYEK 1945, POPPER 1957, COLEMAN 1964, DOUGLAS 1986).This has in the context of strategic management and organisational analysis, led to the question as to the level at which organisational capabilities need to be defined: Is the organization’s knowledge development path or the level of human interaction the primary source of knowledge and knowledge transfer (ARGOTE/INGRAM 2000); is the concept of firm-level capabilities a kind of explanatory shorthand for underlying individual-level action (FELIN/FOSS 2006, 5) or can additional levels – beyond that of the firm - be found in order to explain organizational capabilities and mechanisms of learning?

Institutional economics has always emphasized the multi-level-character of socio-economic analysis: no entity can ultimately be taken as given. It is neither the individual nor the firm which is the sole ‘agent’ in economic and social life –networks are also potentially useful units. They can be interpreted as institutions in accordance with (HODGSON 1998, 171) for whom “institutions play an essential role in providing a cognitive framework for interpreting sense-data and in providing intellectual habits or routines for transforming information into useful knowledge”. According to MASKELL and MALMBERG (1999) clusters (as ‘locally embedded networks’) facilitate the frequent and proximate relations between economic actors that can contribute to the development of a shared cognitive frame. They can serve to fulfil additional functions such as reducing uncertainty about the experimental knowledge of others and increasing the incentives for medium- and long-term investments in diffusion channels. They can thus serve in effect to integrate the positive externalities of innovation, technological knowledge and development activities. Clusters then become economic clubs, which act as institutions for internalizing the problems of effective knowledge transmission (STEINER 2006).Learning – both as a specific form of acquiring and developing capabilities, and as a social process of ongoing development embedded in an institutional and socio-cultural (regional) context – has now become, essentially, a communicative process rather than a cognitive performance, requiring new thinking about the nature and forms of the transmission and dissemination of knowledge within a social and organizational context. Such organizations can be firms as well as networks – and the latter can therefore also be regarded as learning organizations capable of developing capabilities. (STEINER/HARTMANN 1999, 2006). They become then a 'mode of governance' as a form of a Coasian institution and are among the non-market devices by which firms seek to co-ordinate their activities with other firms and other knowledge-generating institutions.

Yet social interaction processes in the form of networks entail a variety of subject matter (HELMSTÄDTER 2003): there are networks of economic transactions and networks of knowledge sharing. The first belong to the process of the division of labour, and deal with the exchange of goods and services, the second, with knowledge. The main differences reside in the form of interaction and in the impact of interaction. Under the division of labour interaction revolves around transaction of goods and services subject to the rules of competition and their redistribution entailing exclusivity. Under knowledge sharing knowledge and skill transfer takes place subject to cooperation and the desire to increase knowledge for all (inclusivity). A further distinction can be drawn. In the former case the processing of goods occurs in specific units; in the latter case internalization and recontextualization dominate.

The most important 'institutional' consequence is that "cooperation is the basic institution of the process of the division of knowledge" (HELMSTÄDTER 2003, 32). But the degree of cooperation depends again on the type of knowledge use: application has stronger competitive elements whereas creation and transfer are dominated by non-economic competition (status, acceptance) and mostly cooperation. The interest lies here in the institutions that make knowledge sharing efficient.

The above distinctions lead to further reflection concerning the forms, channels and mechanisms of knowledge exchange. This exchange occurs through interaction, and the structure of the interaction therefore influences the extent of knowledge diffusion (GAY/DOUSSET 2005). Here, two explanatory approaches exist, but they tend to oppose each other (GIULIANI 2005, 4). The one attributes knowledge with a highly public nature, so that learning, knowledge sharing and innovation within clusters is externality-driven. The alternative approach points to the necessity to include specific features of the firms and of firm-level learning in order to understand the interaction of firm-level and cluster-level learning. The first approach (where Giuliani includes both the economists' perspective on 'localised knowledge spillovers' and the economic geographers' view of cluster 'collective learning') emphasizes the strong relationship between spatial clustering, knowledge spillovers, and firms' innovative output – 'proximity' and 'territory' lead to a quasi-automatic diffusion of knowledge leading to innovation. This automatic mechanism is more put into question by economic geographers, who regard geographical proximity per se as insufficient, and who emphasize the additional role of social and relational proximity in entailing an interactive and cumulative effort by co-localized firms, which nevertheless results in unstructured and diffuse local interactions. The other perspective points to the heterogeneity of firm knowledge base, different firm capabilities, the existence of 'technological leaders' and 'gate keepers' in a local community. These differences do have an effect on the mechanisms by which knowledge is transmitted resulting in the fact that knowledge diffusion is not an accidental collective process but rather structured by the relative distance of firms' knowledge bases (GIULIANI and BELL 2005).

As a consequence of these theoretical approaches and reflections we conclude that cluster theorizing should not attempt universalization –there is not only strong diversity between clusters but also within them. Clusters are highly differentiated across sectors, regions and countries. There is also no single model of knowledge transmission, not even within clusters. Knowledge transfer can not be assumed to be automatic, proximity per se not to be sufficient to generate learning between firms, while the diffusion of knowledge within clusters is both highly selective and strongly dependent of the position of firms within networks, on their knowledge base, and on their absorptive capacity.

These approaches help us to focus our empirical attempt at applying the methods of network analysis in developing a qualitative analysis of clusters. The insights gained by the above reflections are formulated below as tentative hypothesis and serve as guiding principles for our analysis. Thus:

- Networks consist both of material and immaterial links. Material links are predominantly input-output-linkages in the form of market transactions of deliveries. Yet immaterial links in the form of various exchanges of knowledge are the essential element of network activities in the firms involved.
- Networks fulfil different functions and serve different purposes. The interactions within networks therefore assume different dimensions which do not necessarily coincide – from the exchange of goods to the sharing of various kinds of knowledge.
- Depending on their resource-base and strategy not all firms participate in equal intensity in the network and are equally involved in knowledge sharing. Some firms play a leading role in knowledge generation and diffusion, others assume the function of technological leader for knowledge transfer, and many others remain in the background.

- The interaction of firms includes quite diverse activities and constitutes a sort of portfolio of possible interactions, reflecting a variety of needs in situations of uncertainty and bounded rationality.
- Knowledge does not spread evenly within networks – there are distinct points of knowledge creation and diffusion, depending of the role and position of the firm within the network.
- Knowledge networks evolve according to the changing needs of the firms involved. They are not closed systems, but rather temporary alliances between firms.

3 Empirical approach:

3.1 New challenges for the region and for established firms in Styria

The region of Styria (one of the nine provinces – 'Bundesländer' –of Austria) is of special interest for the investigation of clusters dynamics. Suffering from the problems of a typical 'old industrial area' dominated by a large national industry, and being exposed to a new economic situation due to the fall of the Iron Curtain on its border, Styria was confronted with considerable challenges. The 1980s and the beginning of the 1990s were characterized by a low level of growth in regional output, an unbalanced labour market, and structural problems, such as an insufficient rate of firm formation and a low rate of innovation.

In particular, the problems of the steel industry in Upper Styria, turned out to be the major bottleneck for economic development in the time preceding the development of clusters. This region was dominated by large state owned firms that were highly vertically integrated and had lost their headquarter functions in the 1960s and 70s to Vienna. In most cases, planning, R&D and marketing/distribution functions, i.e. those responsible for the monitoring of markets and technology, have been lost. At the end of the 80s large firms were re-privatized and down-sized. Firms needed to learn to collaborate and to develop the potential to innovate as a strategic resource. It was a situation with a very abrupt – and strongly delayed – change, from a Fordist way of production to flexible specialisation.

A massive structural change of the regional innovation system in Styria has been observable since the beginning of the 90s, especially in the street related sectors such as the mechanical engineering sector, the machinery, and the automobile sector. High degrees of diversification and broad unspecified clienteles have been reduced to market niches and technological specialization, and higher lot sizes have enabled a higher integration of functions maintaining flexibility by leaving scope for automatisation. Technological upgrading (including the introduction of quality and measuring standards) also opened doors to a new clientele. Such upgrading has been accompanied by an extension of responsibilities to include tool making and sourcing capabilities, and also by shifting the responsibility for quality and price from clients to suppliers.

Innovation in these sectors was influenced by the availability of specialized knowledge in the field of materials, tooling and processing techniques, or very by the specific problems in the machinery segment. For firms who were already active in R&D a shift from demand-pull driven, to science-push driven R&D seems to be evident.

Industrial restructuring of a region and the building of regional innovation capabilities have to be seen as long term processes which require a bottom-up approach (in particular where SMEs' needs are well understood) and cooperation and permanent communication with national policy actors. The successful catching-up process in Styria since the middle of the 90s is reflected in the innovation-data in all sectors. A first macroeconomic glance at the region offers the impression of high concentrations of economic- activity in a relatively small range of technology fields and industry. The system's learning capacity has been established in a prudent process of stabilization of expectations as a consequence of the informal interaction of agents, who have been confronted with global challenges and competition on the one hand, and with a locally stabilizing knowledge infrastructure, human resource base and immobility of regional agents on the other hand.

The regional government has played a crucial role in promoting cooperation and networks in Styria during the last decade. Actually there are four official cluster organizations in Styria (in the fields of wood, human technology, automotive industry and sustainable technology). Network-orientation also includes policy networks, which help to develop and implement regional strategies in the sense of multi-level governance. Those crucial policy actors, who accompanied the first steps of multilateral firm co-operation and network development, have confirmed that it took a long phase to build up awareness and trust among regional firms, which had been faced by regional disintegration in the phase of belated structural change. The region, and specifically its mechanical engineering and machinery sector, therefore presents itself as ideal for a case study on network activities and as means of addressing the questions outlined above.

3.2 Methods and data

Network analysis is a well established method in the social sciences. Recently, the method has also been applied for the analysis of production clusters (Krätke 2002), innovative activity and knowledge exchange (Giuliani 2005), alliance networks (Gay/ Dousset 2005) or R&D networks.

Social network analysis is a helpful tool in discussing the structure of networks and allows the mapping and measuring of the relationships (communication and transaction) between different actors, that is the existence, context and portfolio of relations between actors in a regional network. It is a method for exposing the underlying relations between different actors, and for revealing those phenomena which cannot be reduced to the properties of individual actors or firms. Thus, relations have to be interpreted as properties of systems rather than of individual actors.

Both, the boundedness of social relations as well as the possibility of drawing relational data from samples, cause selection problems. The boundaries of the core partners of a firm vary from one firm to another. Any definition or measure will tend to be artificial in that it will not allow for all relevant dimensions and features to be captured. Nevertheless, it is necessary to find a compromise between an overarching review of the dimensions of interaction on the one hand and the need to reveal the driving factors in the cluster on the other hand. This paper thus runs along the interface between qualitative regional cluster analysis, quantitative and graphical network analysis, and institution oriented industrial analysis. By combining the quantitative results from network analysis with the outcomes of selective regressions link specific characteristics of firms with their respective position within the network, and by which complementing this with qualitative information based on extensive interviews with the firms, we want to gain insights into the multidimensional behaviour of firms within a given network.

The empirical database

Principally, two approaches of identifying the sample needed for network analysis can be distinguished, a 'nominalist' on the one hand, and a 'relational' approach on the other hand (ZUCKERMANN 2003, Scott 2000, LAUMANN et al. 1983). In the case of the nominalist approach, a priori criteria for the definition of the relevant set of nodes (actors) are imposed. Here we use the relational approach where the relevant nodes are revealed and judged by the actors questioned themselves.

To find the empirical basis for the network analysis we used the snowballing method of sampling in cluster and network investigation. This corresponds with the relational approach, and is developed by means of the references to actors as revealed by previous respondents (FRANK 1979, SCOTT 2000).[1]

The analysis focussed on the mechanical engineering, machinery, and automotive sector forming a well-known cluster in Styria. The starting point was a large system supplier in the automobile sector located in the region. The snowball method led to the identification of firms belonging to different sub-sectors and cultivating related supply-chain and innovation-strategies. Triggered by a citation path of regional suppliers (production or commercialization of goods and services) and of regional partners in the field of research and development (cooperative R&D and related activities and exchange) was followed. Thus the sample was developed stepwise. In this way the data-base for the subsequent network analysis was extended to 23 firms (of which 18 are producer- and five are service-oriented) and nine R&D-institutions. Our network – based on a relational approach using the snowballing method for identification – thus consists of 32 actors, and covers those relations that cross firm (or R&D institution) boundaries. It comprises both heterarchical and hierarchical relations; some of the firms are clearly positioned in a value chain, others have more horizontal relations. The network further comprises firms and R&D institutions within the region – the network analysis therefore describes necessarily, only intraregional relations (extra regional activities – which are an important element – would have to be analysed by other kinds of methods).

The information and data collected are based on extensive qualitative interviews and supported by a quantitative survey concerning specific figures of the firm. The contact persons in the firms have been the general managers (or owners), the heads of the R&D units (as far as existent) and the purchasing agents (as far as existent). In smaller industrial firms most of these functions are held by the owners themselves.

This 32-actor-network does of course not comprise the total cluster. Notwithstanding the generally high willingness to cooperate some firms were not able to reveal all their strategic partners, and some of the Partners indicated (following the idea of the snowballing method) were not willing to participate and to provide the necessary information. The approach nevertheless relies on the assumption that the identified segment of the network is representative for the whole cluster. This is not to unrealistic given the fact that the leading firms and the most important R&D-institutions were included. In addition, the insights gained were complemented by shorter interviews with other firms and with regional experts. All empirical research was conducted in 2005; the time span covered by the empirical data base extends to the period of the last five years, i.e. the answers given by the interviewed persons where supposed to describe the recent past and the present situation.

Descriptive indicators

Among the firms, different types can be differentiated in order to show different necessities, capacities and patterns of research and development. We thus find original equipment manufacturers (OEM), systems suppliers, component Suppliers, toll manufacturers and technical business services.

- An *original equipment manufacturer* (OEM) sells its products under its own brand name. An OEM integrates components and modules bought from other suppliers in its own products which are then sold to the end customers. It is normal for an OEM to bear responsibility for the design and development of the final product.

  Systems Manufacturers are capable of design, development and manufacturing of complex systems. Following a 'black-box' design, this often implies complementary development competences to those of OEMs or system integrators. The boundaries between system supplier and OEM are in our sample very weak, therefore these categories have been pulled together in the following discussion.

- The majority of the suppliers that participate in supply chains in this medium-tech sector work as *component suppliers*, who manufacture and sometimes design a specific component or a simple subsystem. Component suppliers are mostly confronted with a work drawing.

- *Toll manufacturers* are important partners in the machinery sector. Their success is based on specialization, processing knowledge and additional production capacities. Typical examples can be found in the field of heating, surface treatment, cutting machining or welding.
- The *Technical Business Services* observed here operate at very different levels in the sectoral innovation systems.[2]

- The investigation also comprised nine public and semi-public *R&D-Institutions* which also have also identified using the snow-ball method. The landscape of public and semi-public R&D-organisations and institutions in Styria was originally dominated by technical universities (rd10, rd20), an applied research organization owned by the regional government (rd 30), and by traditional industrial R&D-institutes (e.g. rd05). In the middle of the nineteen-nineties the Austrian tertiary education system was extended to include polytechnics. These are more oriented towards education than R&D (rd 40), yet developed small-scale cooperation in specific technology fields with local SMEs. At the end of the nineties a new type of R&D organization was established with the intention of building stronger links between science and industry. These so-called Competence Centres are co-funded by the national and regional government and by the private sector. The idea of such cooperative R&D institutions has been accepted very quickly and has allowed for new methods to develop for allocating pre-competitive R&D at the interface between science and industry.

Table 1 reports descriptive statistics for the organizations included in the sample, i.e. the type of organization, the ownership of the organization, the size of the organization, the size of the R&D-unit (as far as existent), the average exporting intensity, and the age of the organization.

(Insert table 1 here)

Half of the observed firms are not independent but part of different, mostly international, firm groups. The majority of the firms have been situated in the region for more than 10 years. These firms may benefit from the capacity of international firm groups to internalize mechanisms of international integration. The range of observed firms is dominated by medium sized and large firms. This might be caused by the chosen snow-ball sampling approach which starts with a very large system supplier. The R&D capacities of the observed firms varied widely. Nearly the half of the firms has no permanent position for an R&D professional.

Indicators of interaction

Both the quantitative indicators presented, as well as additional qualitative indicators revealing may be helpful for the discussion of individual strategies which finally sum up to the structure of the network. They are used selectively to find – via network analysis - structural features of the network of 32 actors. The selected indicators of the relations cultivated by the organizations cover three dimensions of interaction: direct delivery relations, R&D, and technological innovation in a competitive and a pre-competitive context. The following three dimensions of interaction were employed:

(DELIV): The firms were questioned concerning direct delivery relations (goods or services) to clients, suppliers or partners (in the case of synergetic product bundles).[3] The direct delivery (DELIV) of goods and services is not reduced to the material dimensions but is extended to include innovation-related questions in the context of quality and information management or capacity extending investments. Pre-tests undertaken revealed that firms were not willing to quantify the value of the relation in monetary terms. Therefore the questioned organizations were asked to indicate the frequency of direct delivery interaction according to the following scale: 0 = none (no relation), 1 = low (sporadic and infrequent interaction), 2 = medium (frequent interaction), 3 = high (permanent interaction). The valuation of relations by means of the approximate frequency of interaction gives us the possibility to differentiate stronger and weaker relations.

Two further measures in the context of knowledge generation and transfer were discussed with the institutions interviewed. In order to take account of different R&D capabilities and innovation strategies we distinguished between two dimensions of relations with respect to knowledge generating processes. Both dimensions are in line with the common definitions for R&D and innovation.[4]

(COMP): Competitive Research and Development and innovation processes are short and medium term oriented and mostly associated with direct expectations of return or with a direct tender or offer etc., while pre-competitive R&D is long-term oriented, and research and development activities immediately accompany the treatment of a client order or request. While this includes cooperative R&D as well as unidirectional knowledge-transfer, the strategic dimension seems to be only weakly pronounced. In analogy to the case of direct delivery of goods the questioned organizations have been asked to indicate the frequency of interaction according to the following scale: 0 = none (no relation), 1 = low (sporadic and infrequent interaction), 2 = medium (frequent interaction), 3 = high (permanent interaction).

(PRE-COMP): Another dimension surveyed was the level of interaction in the context of pre-competitive R&D. Pre-competitive Research and Development aims at extending the product spectrum, as well as at introducing new processes and alternative materials. Pre-competitive research includes fundamental research, which is an activity designed to broaden scientific and technical knowledge not yet linked to industrial or commercial objectives, and industrial research, research aimed at developing or improving new or existing products, processes or services as far as it is not directly connected with a client tender, an offer or an existing business relation. These activities have to be pre-financed by the firm and require an additional financial and strategic effort. Pre-competitive R&D does not include routine adaptations of existing products and services.[5] In analogy to the 'competitive-case' relations can be cooperative or unidirectional, e.g. in extramural R&D. Once again the organizations questioned were asked to indicate the frequency of interaction according to the following scale: 0 = none (no relation), 1 = low (sporadic and infrequent interaction), 2 = medium (frequent interaction), 3 = high (permanent interaction).

Basic concepts of network analysis used

The following paragraphs are dedicated to the introduction of the basic concepts of network analysis. This provides the necessary understanding for subsequent discussion. Following the socio-centric approach network density is indicated by the ratio of relations actually realized to the total number of maximum possible relations. We dichotomized the relations. That is, we only differentiate between existence and non-existence of a relation between two actors [0; 1], and therefore disregard for the moment the intensity of the relations (in our case the frequency of interaction) to avoid problems relating to measurement of the density of weighted graphs (Scott 2000, pp. 73ff.)

In the case of the 32 actor network observed in Styria, the maximum possible number of relations, where each actor is related directly with all other players is 992.[6] If there are asymmetric relations, i.e. for some relations *rij* no reciprocal relation *rij* exists, the formula for network density is

$$\frac{\sum rij}{(n\,(n-1))}$$

where $\sum rij$ is the number of relations present and n is the total number of observed actors.[7] The density figure yields information on the general structure of the network as a whole.

One of the core-features of an actor which can be identified in network analysis is his respective centrality. Using the concept of centrality we gain insights into the specific features of the interaction of the actors in the network and their specific position and/or embeddedness in the network.

While the density focuses on the properties and general structure of the network as a whole, centrality tries to capture the position of individual actors or groups of actors within the network. This is again based on the relations which have been revealed by the actors, but here the relations are weighted ordinally with in terms of the frequency of interaction. The potential centrality of an actor is determined by a broad range of industry and sector specific factors (Cohen et al 2000), as well as by capacity, and by individual motivation (BAYONA et al. 2001, THETER 2002). A high centrality is positively associated with the number of possibilities of receiving information and generating knowledge.

Diverse measures of centrality can be differentiated and used complementary to each other. Basically it is possible to make the distinction between the synonymous terms of “point centrality”, “local centrality” or “degree centrality” on the one hand, and “graph centrality”, “global centrality” or “closeness centrality” on the other hand (NIEMINEN 1974, FREEMAN 1979, SCOTT 2000).

The terms ‘degree centrality’ on the one hand and ‘closeness centrality’ on the other hand have been accepted widely in the literature and incorporated into software-tools for network analysis. The concept of degree centrality is based on the idea that actors with high centrality in a network maintain a lot of direct relations to other actors. The degree centrality $C_{D(ni)}$

measures the number of direct relations going out from actor i (out-degree) between two actors i and j. In directed networks a relation can be stated more precisely by the dimensions of ‘reception’ and ‘emission’. In-degree centrality therefore captures the centrality of an actor from the perspective of ‘reception’, while ‘out-degree centrality’ measures the centrality of an actor from the perspective of ‘emission’.[8]

Degree-based centrality can by extended beyond direct connections to include those at various path distances. In graph theory the shortest distance between two points is called the geodesic. The *‘global centrality’ or ‘closeness centrality’,* defined as the sum of all geodesic distances, thus takes into account direct as well as indirect relations to all other actors. *Closeness centrality* is measured by the inverse of the sum of distances from an actor to all the other actors. The closeness centrality $C_{C(ni)}$ can only be calculated in complete networks where each actor is in relation with at least one other actor (otherwise the distance would be infinite). Isolated actors are thus excluded from the calculation.[9]

Analogous to the degree centrality for a directed network (as in our case) *in-closeness centrality* and *out-closeness centrality* is measured separately, depending on whether the distances 'from' or 'to' other nodes are considered.

Beyond the measurement of the centrality of actors by means of direct or indirect relations to other actors another interpretation of centrality are of interest: The ‘betweenness centrality’ measures the significance of the intermediary role of actors resulting from their position in the network. Betweenness centrality is based on the probability that an actor obtains the role of a critical gatekeeper (possibly a bottle neck) in the course of indirect exchange between two arbitrary actors in the network. Gatekeepers play a critical role because they are in a position to control exchange (of goods, information etc.) between different agents. The number of shortest mediate paths (geodesics) is thus set against the number of geodesics crossing the observed actor. [10]

The following discussion of the identified networks is based on the calculation of density and of diverse measures of centrality but also on additional regression analysis which on the one hand aims to identify clear correlations between the structural features of the observed actors and their position in the observed dimensions of networking (DELIV, PRE-COMP and COMP) on the other:

Type of organization: System Suppliers (SYSTSUP), component suppliers (COMPSUP), Technical Business Service (TBS), R&D institution (RD_INST)

Part of a firm-group (FIRMGRP)

Age of the firm (LOG _AGE)

Size of the firm: as function of the logarithmic number of employees (LOG_EMPL)

Size of the R&D unit: as a function of the number of R&D employees (RDEMPL)

R&D intensity: as proportion of employees involved in R&D activities (SHARE_RDEMPL)

Exporting intensity (EXPORT)

3.3 Analysis and results

We begin by focussing on the most striking features of the network and the network dimensions as a whole, and consider the position of individual actors in the network in a latter discussion.

Structure of the network and network density

While the current analysis focuses on regional relations it needs to be kept in mind that interregional and international relations also exist and may be of major priority, as is in fact the case for direct delivery. Table 2 presents the density measure for the three levels of relations between the actors.

(Insert Table 2 here)

Direct delivery relations have the weakest density. Although the datasets have been dichotomized and therefore relations with a very low frequency of interaction have been 'up-graded' the density of the network of direct delivery relations is lower than the density of knowledge intensive innovation-related interaction. As stated in Section 3.1 and confirmed in Table 1 by the figure for exports, most of the firms in the observed network are in the dimension of direct deliveries oriented towards international markets. Regional input-output relations have been reduced in favour of an orientation towards international markets. This is also reflected by average closeness centrality (even when indirect linkages are considered) which is higher among interactions in the context of competitive R&D and innovation processes than among direct delivery relations, although the densities and number of actors involved (nodes) are comparable. While competitive R&D and innovation processes, especially in the case of domestic system suppliers, are partially similar in density to direct delivery relations, the regional density of the network of pre-competitive R&D is much higher. While R&D institutions are of negligible significance in respect of direct delivery relations, the network is based to a considerable degree on relations with cooperative R&D institutions. Beyond the coverage of the total network of actors (including all international relations) our network analysis reveals another explanation for the high density of the network dimension of pre-competitive research and development, namely the permanent relations prevailing among the R&D institutions (e.g. semi-public cooperative research institutions and universities). The lower density of the network COMP in comparison to PRE-COMP may be explained by several factors. Competitive R&D and innovation are to high degree in-house activities owing to time-pressure, but also for reasons of confidentiality. Especially in the case of system suppliers a considerable amount of competitive research and development and innovation processes involves clients and suppliers outside the region and internationally. The relatively high average betweenness centrality conforms to the combinative character of knowledge in this dimension. Regional network analysis encounters a blind spot as far as international relations are concerned since these can not be considered explicitly.[11]

The relational data can be used for a graphical representation of the transaction network of the observed organizations. The network diagram is the traditional and basic methodology for formalizing network analysis and is still a very helpful means of interpretation and discussion. However, clarity suffers the greater the number of actors observed.[12] A quite useful method of graphical representation which is implemented in most of the more or less sophisticated software packages follows the approach of Kamada-KAWAI's (1989) spring embedding algorithm. Taking into account direct as well as indirect relations the shortest path between two actors is defined as the geodesic distance between two actors. The concept of path distance takes into account mediate relations between actors who are not connected directly. Following graph theory the geodesic distance between a pair of nodes is the length of the shortest path (path distance) between two actors. In a directed graph or in an asymmetric matrix of relations, each relation is only considered in terms of its direction. In our case it is again of interest to measure the mean distance, i.e. the average geodesic distance as a measure of network extension.

The aim of this algorithm is to find a set of coordinates in which, for each pair of nodes, the Euclidean distance is approximately proportional to the geodesic distance between two nodes. Based on the approach of Kamada-Kawai, Figure 1 gives an overview of all relations recorded. Figure 1 combines the three dimensions already discussed. The diagram in Figure 1 merges all the dimensions of networking, taking into account the valuation of the relations in terms of their frequency of interaction.

(Insert figure 1 here)

A further interesting dimension of network analysis is the 'coreness' which follows basically the idea of core and periphery. We therefore use the concept of the *k-core* (SEIDMAN 1983, SCOTT 2000). A *k-core* is a sub-graph in which each actor is adjacent to at least k other actors in the sub-graph. That is, for all nodes in the sub-graph the minimum number of the actors' direct relations within the sub-graph is k (in our case eight). The resulting k-core complements the measurement of density, since the latter is incapable of capturing the structural features of the network. The k-core is an area of relatively high cohesion. The symbols for the actors (nodes) correspond to the different types of organizations introduced in Section 3.2. The size of the nodes reflects organisation size. Finally, the length of lines corresponds with the distance between the observed actors. As can easily be seen, we can differentiate between actors who are in the core of the network (coloured black) and actors who are more less on the periphery of the network (coloured white). The diagram makes us aware of the high density of realized relations (calculated in the previous paragraphs). In the k-core of the diagram we can find a group of institutions which seem to interact multilaterally. In the 'core' of the network, we can find R&D institutions, large system suppliers but also toll manufacturers (surface-treatment, heating etc.) which maintain multiple, but weak relations, to a broad range of regional clients.

In the next step, we try to decompose the total network in terms of the three main dimensions of directed exchange. In order to facilitate the visual comparability of the decomposed dimensions of networking we choose circle diagrams. The circle diagram is a very useful method of organizing available data, in that actor can be arranged so as to ensure a minimum overlap among the lines which stand for relations between actors. The position of the actors is identical in all diagrams. The qualities of network diagrams can be interpreted in a way analogous to a matrix. Analogous to the definition of asymmetric matrices we also can identify unidirectional graphs. Again the weighted relations are taken into account. Analogous to the diagram in Figure 1**Error! Reference source not found.** the size of the nodes corresponds to the size of the organisation. The shading indicates the export-rate (white:= ~ 100%; black := ~ 0%). Finally the actors are arranged around their core field of economic competence following the Nace-Classification. As can clearly seen relations along the dimension of direct delivery differ from the relations along the dimensions PRE-COMP or COMP. In the network of direct deliveries relations seem to concentrate in the around large export-oriented systems suppliers in the Nace 34 sector, manufacturers of motor vehicles and vehicle parts, with core competences in the fields of development and assembling. These are served by firms in the same sector but also by component and toll manufacturers in the Nace 27 and 28 sectors responsible for manufacturing of basic metals and fabricated metal products (including die casting, forging or surface treatment) with core competences in the field of metal processing and material science in its widest sense. Finally the system suppliers in the Nace 34 sector are served by finally firms in the Nace 25 sector, the field of manufacture of plastic products, which have a relatively broad client base, and reach beyond the NACE 34 sector. In the networking dimensions PRE-COMP and COMP, R&D institutions are – as expected - prominently involved. A considerable amount of small and medium sized firms are not integrated in this regional dimension of exchange.

(Insert figure 2 here)

Figure 2**Error! Reference source not found.** not only supports the density measure but also indicates that the observed dimensions of networking only overlap weakly. Taking into account the existent relations on the side of direct delivery products and service deliveries on the one hand, and R&D and innovation transfer on the other hand, it is of interest to see which share of relations is exclusively business and delivery driven and which share is exclusively R&D and knowledge driven. [13]

(Insert table 3 here)

- If we take into account only relations on the firm level (see perspective A in Table 3) 16% of the relations between possible partners occur on both dimensions, and are business as well as research and development driven. Only 5 % of the relations are exclusively research and development driven, but 80 % of the regional relations of the network are exclusively driven by direct deliveries or business driven.
- Perspective B again starts from the perspective of firms but includes relations to R&D-institutions. In this case 11% of relations are business as well as research and development based. On the regional level, firms seem to cultivate relations with different partners in different dimensions. Cases where that the business-partner is the core-partner in research and development, or where business partners are related to an R&D institution seem to be the exemption. As might be expected, systems suppliers with R&D capacities and business services, reveal rather more overlapping between business and R&D.

The qualitative interviews confirmed the notion that firm motives for coping with smaller or larger, stronger or weaker, private or public partners are multilayered and depend on a broad range of factors; e.g. competitive conflicts, possible spillovers, bargaining power, resources, available time, strategic relevance of the relation etc. The strategic dimension of a balanced portfolio of relations, including short term arms-length relations on the one hand, and stabile long-term relations on the other, was repeatedly made clear. The dichotomous structure of the observed network seems to be based on a strategic need for balance in the relationship portfolios of the firms concerned.

- For the sake of completeness we add perspective C. This which corresponds with the discussion of the total network and the calculated density measures. If we take into account all observed institutions in the regional network (see perspective C in Table 3) only 9% of the relations between possible partners occur in both dimensions, and are business as well as development driven. 35% of the regional relations of the network are exclusively driven by direct deliveries or business driven. A considerable part of the revealed relations (57 %) is exclusively based on the R&D side.

According to the qualitative interviews undertaken with the observed institutions the network formation described above seems to correspond to an aggregate of the individual strategies as revealed by the interviewed firms. The actors enjoy broad scope in steering their portfolio. They can manipulate frequency of interaction, the time of interaction, the choice of the partner (MARIOTTO/ DELBRIDGE 2001) and the thematic focus of the relationship (specialized or ubiquitous). The choice of partners allows further freedom in that it depends on the level of technological spillovers, prevailing technological and economic capacities, and on the strategic relevance of the reason for interaction. (ATALLAH 2005). The qualitative interviews strengthened the notion that firms seek a portfolio of cooperation partners, and consciously combine specialization and flexibility.

While larger firms with considerable R&D capacity can utilize international contact in research and development activities, smaller low- or medium-tech firms stick to the region and regional partners. Smaller firms are rather confronted with a self-enforcing combination of low R&D capability on the one hand, and unambitious demand from the client's side. Thus, transaction costs are mostly disproportionate to the technological and economic gain expected from co-operation on questions of pre-competitive research and development. The low and medium-tech firms partially utilized opportunities to establish long-term contacts to single public or semi-public R&D institutions which deal with basic technologies –mostly material sciences - in an effort to gain from possible spillovers as a result of activities via appropriate events or informal inquiries. Thus partners in direct delivery and partners in competitive and pre-competitive research and development - as far as existent - are not identical.

Firms with considerable R&D capacity revealed various strategies, depending on their market and co-operation culture. The more these firms act in market niches demanding highly specialized cooperation partners, the more they tend to long-term cooperation involving rather specialized partners.

As far as natural spillovers are high and competitive conflicts are manageable (e.g. in the case of material sciences) larger firms accepts weaker partners - respectively smaller firms - and are willing to integrate them. Low spillovers and higher market orientation favour a conservative sometimes excluding behaviour of the stronger side. This corresponds with the findings of for partner selection in R&D co operations (ATALLAH 2005).

Network positions of individual actors (firms, R&D-institutions)

As mentioned before, our discussion of the position of individual actors is based on complementary qualitative and quantitative sources. Among the diverse measures of centrality regression analyses based on non-parametric regression methods[14] have been employed to identify correlations between structural features of the observed actors and their position in the observed dimensions of networking. The regression analyses tested the ability of the observed characteristics to explain the network-position of the observed actors, supplementary to the results of the qualitative interviews for all dimensions of interaction discussed. In a first step we tested the correlation of the structural features. We were able to identify significant positive correlations for the selected explanatory variables.

The correlation values obtained did not exceed acceptable limits for the regression analysis conducted. The observed correlations basically reflect the specificities of the observed types of organizations. [15]

The results of the regression analysis are summarized in Table 4**Table 4** and are discussed and complemented by results of qualitative interviews with the observed actors in the following paragraphs.

In the dimension of direct delivery relations the central role of the leading firms, which have been the starting point of the investigation (using the snowball sampling method) is reconfirmed by high in-degree centrality.

- As might have been expected the regression analysis (see the model-summary in Table 4) reveals that a high in-degree centrality is positively correlated with a high export intensity. The leading system suppliers where confirmed to be strong recipients of deliveries (Table 4, Model 1) and are also the largest firms in the observed network. Their high in-degree centrality in the observed network can not detract from the fact that a considerable part of intermediate products and raw materials is sourced internationally.

  In the course of the interviews held the observed system suppliers revealed considerably different sourcing strategies, which seemed to be influenced by their industry and industry specific rules of business. The observed large system suppliers of the traditional automobile sector maintain arms length relationships and try to avoid total unilateral dependence which could have ruinous consequences in the case of market fluctuations. Partially, these system suppliers are obliged with concrete recommendations for international suppliers which have been established and registered in their sourcing base.

  System suppliers who belong to international firm groups and directly source most of the intermediate products centrally, have rather weak input linkages, as do component suppliers who source their raw materials from national wholesale-dealers.

Component suppliers, toll-manufacturers and business-services don't play a significant role as recipients of direct deliveries. The lion's share of intermediate products or raw materials is neither sourced from partners in the observed network nor from other actors in the region.

The dimension of closeness centrality does not deviate significantly from the picture drawn for the degree centrality.

- The dimension of out-degree centralities reflects the converse of the above. The regression analysis very weakly indicates a positive correlation of out-degree centrality in respect of direct deliveries for component-suppliers (Table 4, Model 2).[16] The highest out-degree centrality is seen in the case of toll manufacturers (especially surface treatment and heating) and flexible component suppliers with core competences in the fields of die-casting, forging or metal machining and manufacturing of plastics. As can be seen in Table 1, these firms are primarily concentrated in the fields of manufacturing of plastic products, and manufacturing of basic metals and fabricated metal products (including die casting and surface treatment).

The analysis confirms the data amassed from the qualitative interviews: The services of toll manufacturers are sourced locally owing to the transport and logistic costs incurred. Primarily these suppliers mostly act on a regional market. The component suppliers mentioned endeavoured to work in international markets. However, as revealed by all firms interviewed maintaining a certain degree of flexibility and/or a regional client base was regarded as strategically important. The relatively high out-degree centrality can be explained by the fact that such companies offer their goods and services to system suppliers in all technology fields, to, manufacturers of vehicles and vehicle parts but also to manufacturers of precision and measurement instruments. Quite low values of out degree centrality can be identified in the case of system suppliers bound to international firm groups since these exclusively supply their goods to one leading firm in the network.

Looking at the dimensions of R&D (competitive and pre-competitive) it might be expected that R&D-institutions play a considerable role. The regression analysis indicates a high out-degree centrality in of R&D-institutions in this network dimension. Again in this context the size of the organization is of significance.

Actors with higher in-degree centrality are characterized by higher R&D capacities as a function of R&D employees and also by contacts to foreign universities.

The ranking of institutions in respect of closeness centrality does not differ significantly from degree centrality. Closeness centrality more or less corresponds to the idea of spillovers. Institutions which hold a weak portfolio of relations themselves, but engage in exchange with strong nodes ("Stars") can particularly gain from spillovers. Especially firms which cooperate less intensively but are linked to strategic partners, have a better ranking in terms of closeness centrality than is the case for degree centrality. This is true for those firms which are not core-partners of the leading firms but cooperate intensively with knowledge generating institutions.

- In section 3.2 we mentioned the new significance of cooperative R&D institutions in Styria. Along with the technical universities these cooperative R&D institutions have the highest degree centralities in respect of pre-competitive R&D oriented relations. In the case of pre- competitive R&D for the technical universities, we can identify a relatively high in-degree centrality; in addition, firms with higher R&D capacities have higher in-degree-centralities. The latter are system suppliers with R&D competences and technical business services. In contrast to the evidence on to direct delivery relations, nearly all firms which cultivate more or less regular pre-competitive R&D oriented relations to other organizations were found to be regionally focussed.

  Especially in the case of pre-competitive R&D cooperative, publicly supported projects or shareholdings have gained an increasing role during the last decade. In the case of cooperative R&D institutions with a small and closed range of partners, players with notable R&D capacities were found to outsource their pre-competitive R&D partially to these co-operative R&D institutions. Cooperative R&D institutions in the field of material research are more open to a broader range of (weaker) partners benefiting from technology spillovers. The latter, appropriately, have higher degree centralities.

The prominent role, and high centrality values of universities, can also be explained by the existence of continuous low-level exchange (e.g. diploma and doctoral theses) but also by long term, informal personal relationships. In agreement with the concept of absorptive capacity, firms with low R&D and innovation potentials, where innovation mostly has an investment character, were found to have problems building up and maintaining adequate relations with knowledge generating organizations. Surprisingly, single medium tech component suppliers were seen to maintain continuous relationships with knowledge generating institutions particularly when defining, setting up and managing single projects. However, they invested in long-term partnerships with cooperative R&D institutions giving them the chance to source out R&D management on the hand and to gain from possible spillovers on the other. Another non-binding form of dealing with pre-competitive and/or anticipative knowledge generation lies in the support diploma theses.

In general firms engaging in cooperative pre-competitive R&D and in knowledge generation seemed to be seeking adequate equal partners. Nevertheless, two interesting long-term partnerships between small, knowledge intensive technical business services and large system or component suppliers were observed. Both were based on long-term trust and informal exchange.

(Insert table 4 here)

- In the case of competitive R&D the universities still have the highest in-degree and out-degree centrality mainly because they are the long-term partner for large firms in the region. The same is true for larger firms with considerable R&D capacity. In the case of competitive R&D and innovation processes on the firm side, the type of organization and its position in the value chain is significant. As already mentioned in Section 3.2, component suppliers are mostly given a work drawing and toll manufacturers are provided with detailed specifications for the handling of components. These work-drawings and tender specifications are explicit enough and don't require further adaptation or knowledge intensive exchange. The burden of liability is not devolved to the suppliers in such cases.

  System suppliers, who provide non-standardized products ranked particularly high in degree-centrality with respect to competitive R&D compared to pre-competitive R&D. Cooperative R&D institutions, play a less prominent role than in the case of pre-competitive R&D, where in the latter they interact prominently with universities and their core-partners.

As might be anticipated from Figure 1 consideration of betweenness centrality for the observed institutions reflects more or less the picture found in the case of degree centrality. The R&D-institutions play a considerable role as gatekeepers in the regional network. Nevertheless, critical actors in the form of gatekeepers between two sub-networks, and weakly integrated in the network total, could not be identified. Figure 3 combines the perspectives of degree centrality and betweenness centrality (see Figure 3). The radial position marks the degree centrality[17] and the size of nodes the betweenness centrality. Once again, the symbols used for the actors (nodes) correspond to the type of organization.

In the case of direct deliveries a couple of actors were identified who had a significantly higher value for betweenness centrality than for in-degree centrality. These firms were not found in the core of vehicle manufacturing but in the interface with other sectors such as manufacturing of plastic products or measurement techniques. In the dimension of pre-competitive research and development, the universities, together with one cooperative research institution in the field of material sciences, have noticeable roles as gatekeepers and as considerable knowledge providers. In the case of the universities this can be explained by their broad research capacities. The cooperative research institution in question is also an important knowledge provider in the case of competitive research, although its concrete and frequent contacts in this dimension are less wide spread. The leading systems supplier (with considerable R&D capacity) seems to have significant position in the case of competitive R&D and innovation, reflecting their role in knowledge transfer among selected supply partners.

(Insert figure 3 here)

4 Summary and conclusions

The network approach as a ‘socio-metric analysis’ of the cluster of 32 actors within the machinery sector plus related services and R&D-institutions (identified by means of a snowball sampling method), allowed us to describe both the form and content of their respective interactions. We used this approach for a tentative quantification of the different dimensions of interaction within the network and for establishing the position of the actors within the network. Based on the main economic indicators of the firms and on broad qualitative information obtained through in-depth interviews interactions were differentiated in terms of material-based deliveries (business–interactions), competitive R&D and innovation processes, and pre-competitive R&D.

In summarizing and interpreting the detailed results extensively described in the previous Section we can draw several conclusions:

- In its regional dimension the network is strongly based on knowledge intensive relations. The graphical representation of the network relations, its decomposition, as well as the measured densities reveal, that the immaterial dimensions are stronger than the material ones: the highest density was obtained for pre-competitive R&D interactions. While the firms do have extensive supplier relations, these are relatively weak within the region and within the network. However, their knowledge oriented relations are to a large degree regionally concentrated.

- The firms pursue different sourcing strategies; their activities comprise a portfolio of interactions. The different dimensions of interaction coincide only to a small degree: supplier relations are more or less separated from knowledge intensive ones. There is no automatic parallelism of interactions. This does not exclude automatic spillovers of knowledge connected with supplier relations, but it does illustrate that the higher intensities of knowledge exchange as indicated by the revealed forms of interaction are consciously and selectively chosen, and are not a mere by-product.

- The interactions are strongly structured: there are distinct leading actors in the network as a whole, both receiving and emitting more flows than others. Position is mainly dependent on size, export orientation, but also on the respective position in the value chain. Once again, these positions differ according to the type of interaction. Especially in pre-competitive, research local universities and cooperative R&D institutions have an important role and assume gate keeper functions. But firms with higher R&D capacities also take up such a role, indicating the necessity of a well-developed internal knowledge base.

- The growth of new cooperative R&D institutions (competence centres) is an indication that this kind of network relation is rather new and that the pattern of interaction is becoming temporary in character and depends of the existence of specific kinds of knowledge generating institutions.

- The pronounced density of regionally concentrated R&D interaction within the network gives support to the concept of networks as institutions for knowledge exchange.

- In addition to viewing specific persons as generators of knowledge and firms as organizations for R&D we need to include networks and clusters as an additional level of socio-economic analysis.

Our findings help to underline the following:

The concept of clusters is not universally valid – there is not only strong diversity between clusters (depending on sectoral specificities, regional habits, institutional embeddedness) but also within them. They are also to a large degree overlapping phenomena and hence not closed systems. This opens up the possibility of interpreting clusters not only as entities competing against each other but as variety generating units, variety also within each cluster. This supports the interpretation of LOASBY (1998, 78) who views clusters as a "scientific community" which have both the task of restoring tranquillity, and of "devising intimate connections which exploit the advantages of the increasing subdivision of functions within the economy".

Since firms try to establish a variety of types of interaction we can further pursue the idea of HELMSTÄDTER (2003) by distinguishing between the form and impact of these interactions: the exchange of goods obeys the rules of competition, the exchange of knowledge, the rules of cooperation and sharing. In our analysis we found a further distinction: competitive R&D does not lead to such strong numbers and intensities of interaction as pre-competitive research; the latter is dominated by cooperation as the basic institution as process guiding the division of knowledge.

Several methods have identified proximity as a precondition for knowledge. Using network analysis we also found a strong regional dimension for knowledge sharing. As specified above, density of interaction was all the stronger within a given geographic context the more the non-competitive elements of R&D dominated. This result is supported by the qualitative statements supplied by firms: Whereas input-output linkages are only to a small extent regionally concentrated, the opposite is true for knowledge intensive relations – most of them occur within regional boundaries.

Regional networks can be regarded as a selective and geographically concentrated form of cooperation within the larger scales of interaction taking place on a national and international level. The different dimensions and the different intensities of interaction support the interpretation of networks as strategic interfaces between regional and global activities. The various activities within networks constitute a balanced portfolio of relations where actors decide for strategic reasons if and how to take part in networks of different quality and function.

In such a setting knowledge exchange is structured and not ubiquitous. With our analysis we hope to have made the heterogeneous nature of such exchange a little more explicit.

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NOTES

[1] The assumption is that the segment of the network that forms the sample is representative for the whole network. Therefore it required us having a deeper knowledge about the parent population and basic relations.

The value-chain of (knowledge) production refers to the sequential set of primary and support activities that are performed to turn inputs into value-added outputs for its external customers. In our case therefore small trade business, handicraft business or business services like cleaning services, security services etc. which are not substantially integrated in the value chain of (knowledge) production have not been included in the analysis. As far as the value chain of (knowledge) production can be retraced in the region the observed network largely covers the total network of the leading firms. There are evidences for a certain robustness of network measures even under conditions of imperfect data (BORGATTI, CARLEY, KRACKHARDT 2006). Within the defined dimensions of the investigation a nearly complete inventory count can be assumed.

A matching of the characteristics of the observed firms with those of a control group out of the general population (i.e. the total sector) was undertaken to take into account the representativeness of the chosen sample. The assessment of representativeness has been based on 15 interviews with relevant firms in the sector which has been carried out in a pre-phase. For this purpose these 15 firms have been asked for their sourcing and cooperation strategies, their size and characteristics of their partners in the region and four leading firms finally on this basis selected.

[2] One firm (BS 1)for instance is a first class technology provider with an export intensity of above 95% but with a considerable anchorage in the regional innovation system, where participation in cooperative competence centres will be accentuated. Another interesting case (BS 4) is an export oriented business service firm which is embedded and active in the politically-initiated automobile cluster in Styria but lacks a regional key-customer base. BS 3 is an engineering service firm with industrial customers in the field plastic products and composite materials, scientific partners and a pro-active strategy of integration into the regional science community. BS 5 is a small service firm in the border region of Slovenia which is a supplier to the leading system supplier or BS 1 and has received direct support from the leading systems manufacturer during the past years. BS 2 is a small R&D-Service which works almost exclusively for a knowledge intensive firm in the field of measuring equipment.

[3] The dimension of supply-chain-networks is a function of vertical integration and division of labour in an industry. The automobile and aerospace industry are the mascots of empirical investigations of supply chain networks and relations. They are special cases because middle or high volumes of products with a relatively high number of individual parts are produced by specified routines. Regional clients in other areas of the machinery sector with limited batches or individual lot orders impose limits on medium and long-time strategic planning, on automation, or on long-term growth. Given the importance of the systems being subcontracted

by assemblers, there is a clear strategic goal for these firms to work with a smaller number of large suppliers.

[4] Official Journal C 48 of 13.02.1998, Official Journal C 111 of 08.05.2002 European Commission

[5] We focused on three dimensions of direct exchange between the interviewed firms. Another dimension of weak partially undirected relation between regional actors which has been addressed in the interviews is informal exchange, in the course of trade fairs, events organized by cluster-, business-promotion organizations or business-associations. This dimension of interaction can not be operationalized for network analysis, albeit its significance may by no means be underestimated as previous research verified (STEINER, HARTMANN 2006).

[6] If also the direction of relations is accounted and asymmetric relations exist the number of maximum possible relations

$rmax = (n \times (n - 1)) / 2$, where n is the total number of actors (possible nodes in the network).

[7] It seems appropriate to assume that each actor has limited relational capacity. The density of a network of relations usually decreases with the number of observed actors; therefore it is not possible to compare density measures across networks of different sizes (SCOTT, 2000, FRIEDKIN 1981).

[8] The degree centrality for actors in directed asymmetric networks is measured in the following way: Only the formula for the out degree centrality is presented, which is defined analogously to the case of the out-degree of actor i. The distorting effects of the size of the network can be neutralized by standardizing with respect to the maximum possible value of n-1, where n is again the number of actors.

$$C'_D(n_i) = od_i / (n-1)$$

[9] The formula for the standardized closeness centrality C'C(ni) is

$$C'_c(n_i) = \frac{N-1}{\sum_{j=1}^{N} d(n_i, n_j)}$$ for i $\neq$ j

[10] The betweenness centrality CB(ni), is defined as

$$C_B(n_i) = \sum_{j<}^{n} \sum_{k}^{n} b_{jk}(n_i)$$ for i $\neq$ j $\neq$ k where $$b_{jk}(n_i) = g_{jk}(n_i) \frac{1}{g_{jk}}$$

The maximum centrality is dependent on the size of the network. The standardized betweenness centrality is defined by the formula

$$C'_B(n_i) = \frac{2C_B(n_i)}{n^2 - 3n + 2}$$

[11] The merging of all dimensions provides a network with a standardized total density of 0.226, which is a remarkably high value. The possible density of the network decreases as one moves from core to periphery. Thus extending the sample using snowballing would result in a lower total network density.

[12] Even in the case of a network of 32 actors with a relatively low density the number of cross-cutting relations causes confusion to a certain degree. This is all the more evident for a network with a density of 0.223.

[13] To aid clarity we dichotomized and symmetrised the relations here under consideration, This means that the definition of all relations is reduced to the question of whether they are present or not irrespective of frequency and direction of interaction.

[14] The assumption of the independence of statistical observations, which is a prerequisite for standard OLS-estimations cannot be held in the case of social network analysis (SCOTT 2000. The alternatively employed regression algorithm performs in first step a standard multiple regression across corresponding cells of the dependent vector (the observed degree centralities) and independent vectors (selected characteristics of the actors in the network). In a second step the regression is recomputed by random permutations (50 000) storing resultant

values of r-square and all coefficients. Based on this procedure estimates of standard error and "significance" are computed. The regression analysis was conducted for each degree-centrality (dependent variable) on the basis of the following explanatory variables:

- Dummy variables for the type of organization (business services (TBS), systems suppliers (SYSTSUP), component suppliers (COMPSUP), R&D-Institutions (RD_INST)) and one dummy variable for 'part of a form group' (FIRMGRP)
- Metric variables for the age of the institution in the region (LOG _AGE), the size of the organization as a function of the logarithmic number of employees (LOG_EMPL), the size of the R&D-units (RDEMPL), the R&D-Intensity as a proportion of employees involved in R&D-Activities (SHARE_RDEMPL) and finally the export intensity (EXPORT)

The analysis has been conducted in two sequential steps: firstly with a single-step variable selection approach and secondly a stepwise variable selection approach (both based on 50 000 permutations).

[15] Significant results of the correlation analysis are:

- In respect of the type of organization the characteristic 'system supplier' (SYSTSUP) is positively correlated with the size of the firm (LOG_EMPL) and the exporting intensity (EXPORT).
- The characteristic 'R&D-Institution' (RD_INST) is positively correlated with the R&D-Intensity measured by the share of R&D-employees (SHARE_RDEMPL).
- The size (LOG_EMPL) of the organization is positively correlated with export intensity (EXPORT) and with the size of the R&D-unit (RDEMPL).

The results of the correlation analysis are summarized in detail in the Annex (**Error! Reference source not found.**).

[16] It has to be remarked, that the final model 2 is only able to explain a relatively small share of the total variance.

[17] The radial scales of the figures are different for ease of presentation.

Degree-centrality focuses on the significance of an actor either on the demand- or supply side. Betweenness focuses on both sides (in and out). It is thus possible to illustrate six combinations of degree- and betweenness centrality.

We selected the most interesting ones for figure 3. In the case of direct delivery in-degree centrality has been chosen and in the dimensions of research and development the out degree centralities are used.

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ANNEX:

Table 5 Correlation coefficients of degree centralities and structural characteristic of firms –

A comparative view of the observed dimensions of interaction

	RD_ INST	TBS	SYST SUP	COMP SUP	FIRM GRP	LOG _AGE	LOG_ EMPL	RDEMP L	SHARE_ RDEMP L	EX PORT	in-degree DELIV	out-degree DELIV	in-degree PRECO MP	out-degree PRECO MP	out-degree COMP
TBS	-0,269														
SYSTSU P	-0,391*	-0,269													
COMPS UP	-0,269	-0,185	-0,269												
FIRM GRP	0,209	-0,086	0,07	-0,086											
LOG _AGE	0,04	0,028	-0,389*	0,291	-0,531**										
LOG_E MPL	-0,141	-0,256	0,521**	0,06	-0,04	0,091									
RDEMP L	0,091	0,057	0,131	-0,186	0,174	0,058	0,668**								
SHARE_ RDEMP L	0,77**	0,177	-0,395*	-0,361*	0,306	-0,02	-0,268	0,146							
EXPORT	-0,534**	0,202	0,476*	-0,032	0,125	-0,051	0,463*	0,299	-0,393*						
in-degree DELIV	-0,332*	-0,076	0,531**	0,012	0,229	-0,193	0,677**	0,669**	-0,254	0,647**					
out-degree DELIV	-0,504**	0,022	-0,249	0,413*	-0,414*	0,288	-0,134	-0,295	-0,491*	0,098	-0,08				
in-degree PRECO MP	0,68**	-0,054	-0,095	-0,381*	0,215	0,008	0,303	0,52**	0,656**	-0,035	0,162	-0,527**			
out-degree PRECO MP	0,772**	-0,098	-0,178	-0,34*	0,145	0,12	0,259	0,438*	0,658**	-0,178	0,017	-0,554**	0,962**		
in-degree COMP	0,254	-0,179	0,161	-0,215	0,124	-0,054	0,547**	0,581**	0,195	0,182	0,505**	-0,243	0,695**	0,635**	
out-degree COMP	0,447*	-0,262	0,06	-0,193	0,088	0,023	0,511**	0,636**	0,272	0,031	0,437*	-0,308	0,747**	0,723**	0,853**

Table 1 Descriptive indicators of the observed actors in the network

Type of the organization	**system suppliers**	**component suppliers**	**toll manufacturers**	**business services**	**R&D – institutions**	**Total**
N	9	5	4	5	9	32
(%)	28	15.6	12.5	15.6	28.1	100.0
individual firm (N)	4	3	3	3	3	16
part of a firm group (N)	5	2	1	2	6	16
industry						
Manufacturing of rubber and plastic products (25)	0	2	1	0	0	3
Manufacture of basic metals and fabrited products (incl forging, surface treatment and heating) (27, 28)	0	2	3	0	0	5
Manufacture of precision and optical instruments (33)	1	0	0	0	0	1
Manufacturer of motor vehicles, trailers and other trailers (34)	8	1	0	0	0	8
Business Servises (74)	0	0	0	5	0	5
R&D (73)	0	0	0	0	6	6
Universities, Educ. (75)	0	0	0	0	3	3
size of the organization (categor.)						
small-sized org. (up to 49 empl.)	0	0	2	4	4	10
medium-sized org. (50 to 249 empl.)	2	3	2	0	1	8
large organization (250 and more empl.)	7	2	0	1	4	14
size of the R&D-unit (categor.)						
no R&D employees (N)	2	5	3	0	0	10
1 to 3 R&D employees (N)	0	0	1	3	0	4
4 to 7 R&D employees (N)	3	0	0	0	2	5
8 to 15 R&D employees (N)	4	0	0	2	7	13
above 15 R&D employees (N)	2	5	3	0	0	10
average exporting itensity (mean in %)	68,67	20,25	27,8	49,8	~	~
age of the organization (categor.)						
1 to 3 years (N)	3	0	1	0	1	5
4 to 7 years (N)	1	2	0	0	2	5
8 to 15 years (N)	1	0	0	2	2	5
above 15 years (N)	4	3	3	3	4	17

Table 2 Density of the observed dimensions of networking and average degree, closeness and betweenness centralities

Relational dimensions		*Number of actors involved (nodes)*	*Density*	*Average degree centrality*	*Average closeness centrality*	*Average betweenness centrality*
(DELIV)	direct delivery relations	25	0.07	0.07	0.08	0.00
(PRE-COMP)	interaction in the context of pre-competitive R&D	23	0.14	0.15	0.27	0.01
(COMP)	interaction in the context of competitive R&D and innovation activities	25	0.07	0.08	0.20	0.03
Overall network		32	0.23	0.22	0.46	0.03

Figure 1 Network of firms and Knowledge generating institutions in Styria

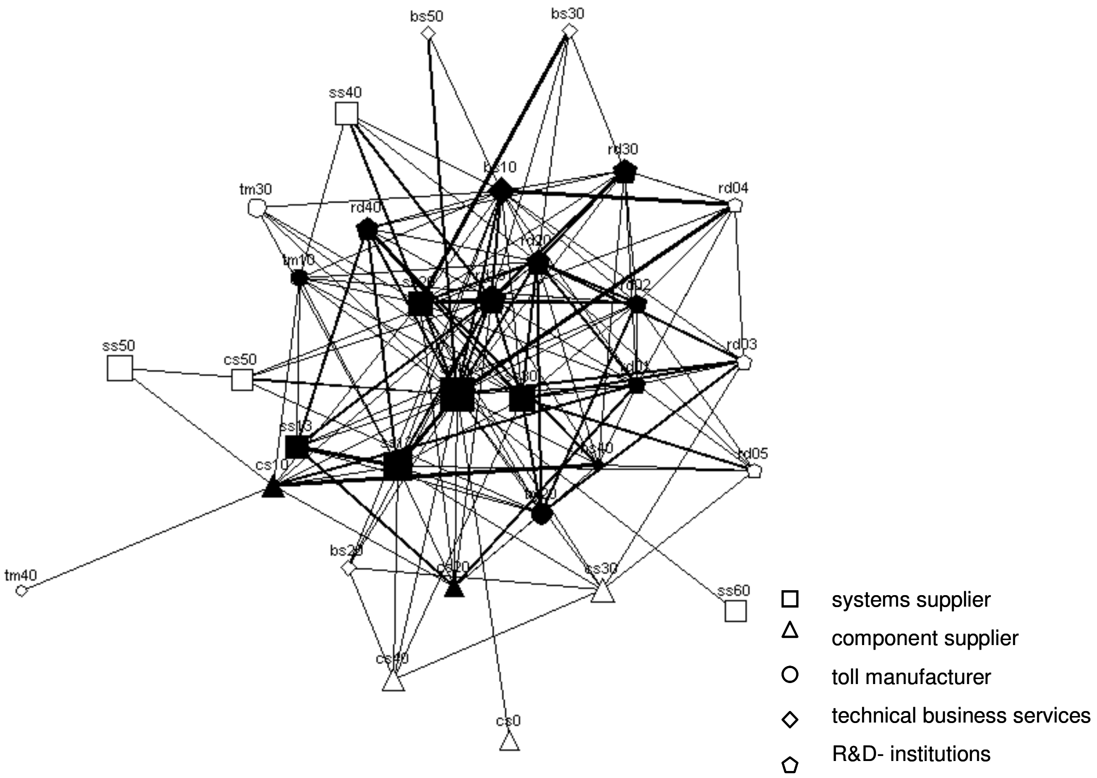
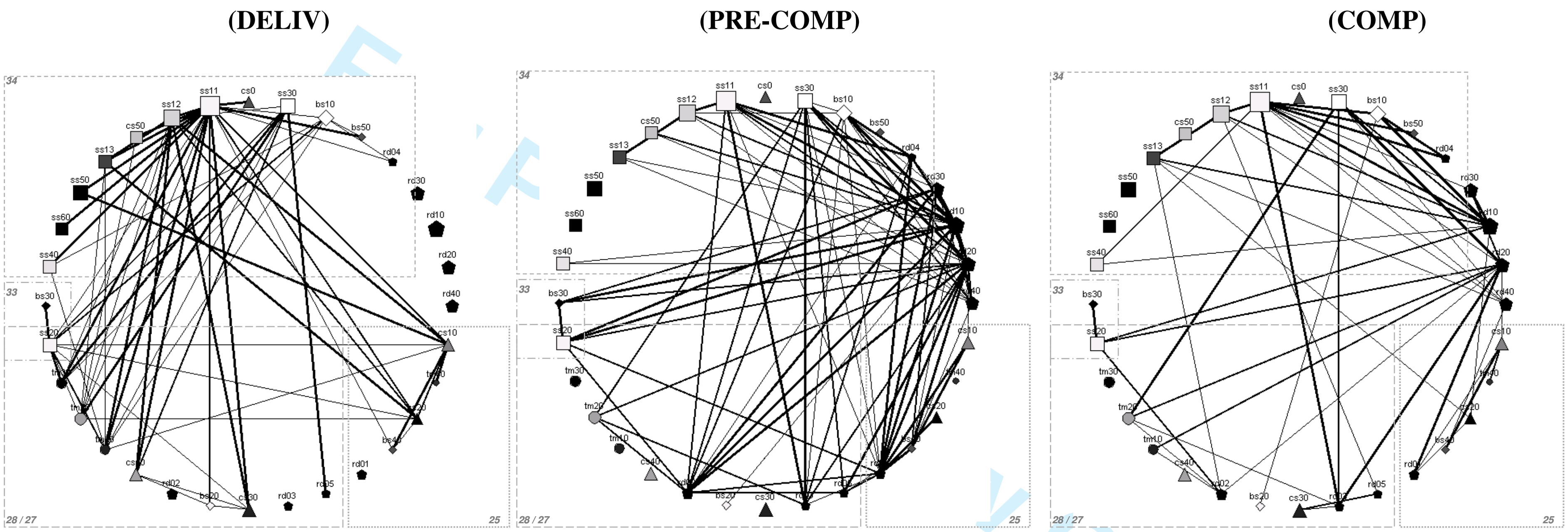


Figure 2 Comparative presentation of the observed dimension of networking



- □ systems supplier
- △ component supplier
- ○ toll manufacturer
- ◇ technical business services
- ⬠ R&D- institutions

Table 3 Overlapping of the observed dimensions of networking (% of the number of relations)

Perspectives (in %)	*excl. direct - Deliveries (DELIV)*	*direct Deliveries (DELIV) as well as Interaction in the context of R&D (PRE-COMP or COMP)*	*excl Interaction in the context of R&D (PRE-COMP or COMP)*
perspective A: *inter-linkages between firms*	79.37	15.87	4.76
perspective B: *interlinkages of firms with other firms in the region and R&D Institutions*	40.98	10.66	48.36
perspective C: *interlinkages in oberserved total network*	34.48	8.97	56.55

Table 4 Regression coefficients for the correlation between degree centralities and structural characteristic of firms –

A comparative view of the observed dimensions of interaction

	Interaction by direct deliveries (DELIV)						
	Model 1: in-degree centrality				**Model 2: out-degree centrality**		
	One-Step Variable Select.		**Stepwise Variable Selection**		One-Step Var. Select.	**Stepwise Variable Selection**	
	R^2		***R^2***	***F***	***R^2***	***R^2***	***F***
	0.816		0.74	25.8	0.731	0.2	6.8
	Beta	**Sg**	**Beta**	**Sg**	**Beta**	**Beta**	**Sg**
(Constant)	0.063				0.152		
RD_INST	-0.047				-0.168		
TBS	-0.061				-0.12		
SYSTSUP	0.073		**0.084**	**0.096**	-0.164		
COMPSUP	0.086				-0.045	**0.08**	**0.02**
FIRMGRP	-0.015				-0.044		
LOG _AGE	-0.038				-0.017		
LOG_EMPL	-0.021				0.027		
RDEMPL	0	*	**0**	**0.029**	0		
SHARE_ RDEMPL	0				0.001		
EXPORT	0.001	*	**0.001**	**0.061**	0		

	Interaction in the context of pre-competitive R&D (PRE-COMP)						
	Model 3: in-degree centrality			**Model 4: out-degree centrality**			
	One-Step Incl.	**Stepwise Variable Selection**		One-Step Variable Select.		**Stepwise Variable Selection**	
		R^2	***F***	***R^2***		***R^2***	***F***
	0.79	0.46	25.8	0.813		0.74	40.2
	Beta	**Beta**	**Sg**	**Beta**	**Sg**	**Beta**	**Sg**
(Constant)	-0.06			-0.168			
RD_INST	0.135	**0.205**	**0.000**	0.257	*	**0.294**	**0.000**
TBS	-0.018			0.048			
SYSTSUP	-0.051			-0.028			
COMPSUP	-0.05			-0.055			
FIRMGRP	-0.029			-0.006			
LOG _AGE	-0.024			0.013			
LOG_EMPL	0.072			0.095		**0.086**	**0.018**
RDEMPL	0			0			
SHARE_ RDEMPL	0.002			0.001			
EXPORT	0.001			0			

	Interaction in the context of competitive R&D (COMP)						
	Model 5: in-degree centrality				**Model 6: out-degree centrality**		
	One-Step Variable Select.		**Stepwise Variable Selection**		One-Step Incl.	**Stepwise Selection**	
	R^2		***R^2***	***F***	***R^2***	***R^2***	***F***
	0.524		0.43	10.7	0.646	0.56	18.3
	Beta	**Sg**	**Beta**	**Sg**	**Beta**	**Beta**	**Sg**
(Constant)	0.001				0.038		
RD_INST	-0.012				0.084	**0.071**	**0.018**
TBS	-0.061				-0.041		
SYSTSUP	-0.061				-0.018		
COMPSUP	-0.043				-0.003		
FIRMGRP	-0.02				-0.034		
LOG _AGE	-0.028				-0.022		
LOG_EMPL	0.058	*	**0.067**	**0.000**	0.023		
RDEMPL	0				0	**0.0**	**0.001**
SHARE_ RDEMPL	0.001		**0.001**	**0.027**	0		
EXPORT	0				0		

Figure 3 Illustration of degree centrality and betweenness centrality