Published as: Bentlage, M., Wiese, A., Brandt, A., Thierstein, A. Witlox, F. (2014). Revealing Relevant Proximities. Knowledge Networks in the Maritime Economy in a Spatial, Functional and Relational Perspective. *Raumforschung und Raumordnung*, vol. 7, pp. 275-291.

Entstehende Nähe: Wissensnetzwerke in der maritimen Wirtschaft in räumlicher, funktionaler und relationaler Perspektive

Michael Bentlage [1]
Anne Wiese [1]
Arno Brandt [2]
Alain Thierstein [1]
Frank Witlox [3]

Affiliation and address:
[1] Technische Universität München, Arcisstr. 21, 80333 München
[2] CIMA Institut für Regionalwirtschaft GmbH, Moocksgang 5, 30169 Hannover
[3] Ghent University, Department of Geography, Krijgslaan 281, S8, B9000 Ghent - Belgien

Abstract

Die maritime Wirtschaft als ein heterogenes Innovationssystem hat großen Einfluss auf die räumliche und funktionale Entwicklung von urban Räumen und Hafenstädten. Die stetige Weiterentwicklung der Wissensbasis in der maritimen Wirtschaft steht in enger Verbindung mit räumlichen Strukturen und lässt Nähe zwischen diesen Räumen entstehen. Dabei ergänzen sich Wissensressourcen auf verschiedenen Maßstäben von lokal bis zum global gegenseitig und fügen dem wirtschaftlichen Strukturwandel in Städten eine globale Dimension hinzu. Konventionelle Klassifizierungen auf Grundlage der Wirtschaftsbereiche reichen dazu nicht aus, um die ‚Verräumlichung' von Wissen zu verstehen. Eine relationale Perspektive auf Wissensnetzwerke im Zusammenhang mit dem realen Austausch von Gütern ist eher in der Lage, dieses Verständnis zu fördern. Dieser Beitrag versteht die Wissensproduktion als interaktiven Prozess, der auch mit der Produktion von Gütern verflochten ist, und untersucht die Anwendbarkeit verschiedener Wissenskonzepte auf die Kooperationsnetzwerke in der maritimen Wirtschaft in Deutschland. Dabei erarbeiten wir eine induktive Herangehensweise, die sich mit den Funktionen und Tätigkeiten der Unternehmen und Forschungseinrichtungen auseinandersetzt und dabei Zusammenhänge von räumlicher und relationaler Nähe analysiert. Wir wenden dabei die Soziale Netzwerkanalyse im räumlichen Kontext an. Dadurch wird ersichtlich, dass das Netzwerk der maritimen Wirtschaft hauptsächlich von Dienstleistern, Schiffsbauern und Forschungseinrichtungen zusammen gehalten wird. Die Städte in Norddeutschland formen dadurch im Ansatz ein hierarchisches Netzwerk, in dem Hamburg die höchste Bedeutung und als Gatekeeper funktioniert. Jenseits dieser hierarchischen Netzwerkstruktur etablieren sich spezialisierte Standorte entlang der Ems-Achse.

Keywords:

Maritime Wirtschaft, Wissen, räumliche Entwicklung, Nähe, urbanes System, Deutschland

Revealing relevant proximities: Knowledge networks in the maritime economy in a spatial, functional and relational perspective

Michael Bentlage [1]
Anne Wiese [1]
Arno Brandt [2]
Alain Thierstein [1]
Frank Witlox [3]

Affiliation and address:
[1] Technische Universität München, Arcisstr. 21, 80333 Munich, Germany
[2] CIMA Institut für Regionalwirtschaft GmbH, Moocksgang 5, 30169 Hanover, Germany
[3] Ghent University, Department of Geography, Krijgslaan 281, S8, B9000 Ghent - Belgium

Abstract

The maritime economy as a heterogeneous innovation system has ongoing relevance to the successful spatial and functional development of port city regions in Europe. A strong technological knowledge base underpins the competitiveness of maritime economy which is grounded in distinct spatial structures and proximities. The simultaneous relevance of global and local knowledge is particularly pronounced in the maritime economy through its inherent relevance to globalization and structural change. Conventional classifications embedded in the discussion of the spatialization of knowledge intensive activities and global value chains, however, limit the analysis to certain parts of the maritime cluster. This paper looks at the applicability of various discourses on knowledge generation as an interactive process, based on a comprehensive dataset derived from cooperative links within the maritime economy of northern Germany. It suggests a framework for analysis, which is activity based and focused on the concurrent presence of different dimensions of proximity across value creating systems. We explore spatial patterns by means of social network analysis, which are industry-specific and have the potential to inform efforts to increase functional as well as physical connectivity in Port City regions. The empirical analysis sets out from the individual firm as an actor seeking to optimize its location for the purpose competitiveness. It proposes an approach, which is routed in the ongoing discussion on spatial and functional dispositions for innovation activity and bridges the dichotomy of knowledge intensive services and manufacturing activities in the maritime economy.

Keywords:

Maritime Economy, Knowledge Networks, Spatial Development, Proximity, Urban System, Germany

1 Introduction

The spatial organization of industrial activities has undergone dramatic change in the past 50 years (Dicken 2011). Globalization and the rise of information and communication technologies (ICT) have propelled the restructuring of value chains and knowledge networks (Derudder and Witlox 2010; Brown et al. 2010). The maritime economy has been instrumental to economic change and forming of the urban system in Germany by producing knowledge and innovations. However, the resultant spatial patterns have been successfully traced by following shipping lines and exploring on- and off-loading data (Jacobs/Koster/ Hall 2010; Jacobs et al. 2010). This development process comes along with the restructuring of port activities and a renewal of port city-regions (Notteboom/ Rodrigue 2005) combined with a process of *up-scaling* and emerging Mega-City Regions (Hall 2007: 5-8). Thus, there is more to the maritime economy than just trading goods.

In particular, there are five specific characteristics to the maritime economy. Firstly, the activities involved transcend the sectors around transport, services and manufacturing. At the same time, the value chains reach from low-tech manufacturing to knowledge intensive industries where knowledge production is interlinked with the transformation and exchange of goods. Secondly, the maritime economy is strongly affected by structural change which fosters the importance of advanced producer services as intermediates in the production process on the one hand and the relocation of labour intensive parts on the other. Thirdly, by means of its logistic service, it is the "plumbing" of globalization, as 90 percent of goods are traded by ships (Rodrigue 2013). Fourthly, the maritime economy and its physical presence not only revolves around port facilities but also includes activities and places remote to coastal areas (Brandt/Dickow/Drangmeister 2010: 238). Finally, the maritime economy is embedded in a certain interrelation between ports and cities nearby (Hall/Jacobs 2012). Thus, the maritime economy affects spatial development by a number of parallel processes.

By studying the activities contained within the maritime economy, we aim to improve the understanding of the emerging differentiation of spaces around port cities. Waterfront regeneration, logistic poles, port expansion, infrastructure planning and urban expansion leave a disparate image of European port cities in terms of economic success (Schubert 2009; Hein 2011; Hall 2007). Due to knowledge networks and division of labour, the maritime economy evokes distinct patterns of proximities between urban areas. Moreover, the maritime economy which is heterogeneous in nature represents a complex innovation system in which physical flows of goods are interwoven with a non-physical dimension of knowledge in transfer. Therefore, the maritime economy provides a unique opportunity to assess the spatiality of knowledge networks beyond the facilities of ports (Hesse 2010; Brandt/Dickow/Drangmeister 2010: 241). Generally, it is assumed that knowledge spillovers require face-to-face contacts for economic success. This understanding was established in the field of agglomeration economies (Eriksson 2011) and evolutionary economics (Boschma/Martin 2010). However, it has been argued elsewhere, that a further differentiation in accordance to knowledge types is needed to explain the spatial organization of economic activities (Growe 2012). Therefore, an industrial process-based approach is more applicable (Bryson/ Daniels 2010; Amin/Cohendet 2004).

This research topic requires an analytical approach, which takes the heterogeneity of the maritime economy into account and further reflects innovation oriented cooperation on value-added relations. We apply a closer and inductive look at the composition and relationships within the maritime economy in order to evaluate the role of knowledge transfer for economic success, the interdependence of activity fields and in between of spatial co-location and distant collaboration.

Thus, we analyze the maritime economy from three perspectives: Firstly, we investigate the relations of different fields of activities within the maritime economy. Secondly, we show that the entire network of the maritime industry devolves into certain sub-networks, which rely on spatial qualities and sectorial composition. Thirdly, due to the fact that knowledge production is interlinked with the exchange and transformation of material goods we include value added characteristics in order to investigate the spatial range of the knowledge relations.

To gain insight into the character of activities and relationships within the maritime economy the second section of this paper sketches the relationships among the activity fields involved in the maritime economy. The third section elaborates the theoretical background of the analysis and discusses knowledge generation with regard to differences in the nature of knowledge and patterns of proximity. Section four introduces the set-up of analysis and the used data. Section five presents the empirical findings which demonstrate the validity of this differentiated approach by applying network analysis in order to study how knowledge interaction and spatial proximity are interrelated. The sixth section discusses the approach and methods used. Finally, the conclusion in section seven summarizes our findings with regard to the urban system in northern Germany.

2 The Maritime Economy as conglomerate of sectors

As a heterogeneous cluster of activities the inner logic of cooperation and innovation is critically affected by the flow of knowledge within and across activity fields. The maritime economy consists of 13 different activity fields (Brandt/Dickow/Drangmeister 2010). These are: boat building, port corporations, port logistics, maritime services, maritime education and professional development, maritime science, marine engineering, marine engineering science, shipping companies, shipbuilding, shipping supplier and other economic and science actors. The knowledge intensity varies across and within these activities. Therefore, we adopt a definition which is applicable to cross sectorial activities and different functional profiles. Hall (2007) considers all those activities as knowledge intensive, whose ratio of highly qualified personnel is above the average of all services (Hall 2007: 49). More specifically, Legler and Frietsch (2006: 22) define shipbuilding and shipping as knowledge intensive branches.

The maritime economy transcends the economic sectors of Manufacturing (NACE Section C), Professional, Scientific and Technical Activities (NACE Section M), Transportation and Storage (NACE Section H), Education (NACE Section P), Administrative and Support Service Activities (NACE Section N). Other sectors, which might be of relevance in certain activity fields are Construction (NACE Section F) and Financial and Insurance Activities (NACE Section K). The NACE classification draws on economic activities by using common resources: "capital goods, labor, manufacturing techniques or intermediary products are combined to produce specific goods or services" (Eurostat 2008: 15). Thus, it is a framework focusing on input-output relations and a commonly used production base.

However, what is more important for the assessment of knowledge flows is the interrelation of the aforementioned activities and the inter-linkage with non-market relations within the industrial cluster. In regards to innovation activity the exchange of knowledge is not only critical for the development of new products and services but also for the brokering of uncertainty involved in such a process. Podolny (2001) argues that in order to successfully develop and place an innovation, firms draw on resources and information from their network but also need to gain visibility, which enables them to find or be found by exchange partners. This dichotomy of transformation and transaction based activities is of particular relevance to the maritime economy (Podolny 2001).

3 Theoretical background: Knowledge in transfer and proximity

Our understanding of the maritime economy, in which knowledge production is interwoven with the trade and production of goods, and its relevance for spatial development processes is based on three constituent parts: firstly, the nature of its knowledge base and its reference to spatial and relational proximity. Secondly, the social process of knowledge creation, as it is interwoven with the production and trade of material goods. Thirdly, innovation considered as the valorization of generated knowledge and the ultimate driver of economic development. This process of interactive knowledge generation evokes a complex interplay between spatial and relational proximity. The latter emerges due to the activities of people evolving in socially situated practices while innovating. Therefore, we derive at an understanding in which the intersection of manufacturing, research and development and advanced services is emphasized. Agglomeration economies provide a profound resource to address these subjects (Thomi/Sternberg 2008).

3.1 The nature of knowledge

Knowledge is a production factor for both the input and the output side of value added (Amin/ Cohendet 2004: 15). In order to transform knowledge into value, firms or people apply specific competencies. Knowledge as an output is provided for instance by innovation, which is defined as invention brought to markets. When it comes to a spatial analysis and organized learning a differentiation of knowledge is required.

Since Polanyi (1966) published his work *The tacit dimension* (Polanyi 1966), it is acknowledged that knowledge has a strong spatial relation, and that codified and tacit knowledge are mutually depending (Kujath/ Schmidt 2010). Whereas codified knowledge might be transmitted via ICT without any *friction losses*, tacit knowledge is considered as geographically located or socially embedded (Amin/Roberts 2008). Gertler (2003) provides three arguments for the spatial foundation of tacit knowledge: firstly, tacit knowledge is difficult to exchange over long distances since it is rooted in experiences one makes in learning processes. Secondly, it is context specific in terms of language, shared values or culture. Finally, the innovation process turns into a social event in which learning structures become relevant and, thus, it involves institutions and organizations enabling access to learning (Gertler 2003: 78-79).

Gertler (2008) suggests a further distinction between analytic, synthetic and symbolic knowledge to capture the systematic differences in knowledge bases and innovation processes across industries. Analytical knowledge predominates in those industries where scientific knowledge derived from deductive models is highly important. This includes activities such as engineering and research. This type of knowledge tends to be codifiable and therefore less dependent on physical proximity for its exchange. The dominant innovation mode is radical as opposed to incremental. Synthetic knowledge however, dominates in sectors where innovation originates from the application and re-combination of existing knowledge. This knowledge type is for example present in consulting activities, where services are individually customized based on previous experiences. It tends to be driven by specific problems, which arise from the interaction with clients and suppliers. The dependence on a particular context, set of routines and practical skills make it less codifiable and more dependent on the tacit dimension. Spatial proximity is considered a necessary prerequisite for the exchange of synthetic knowledge. Symbolic knowledge, which is applied in activities in media and advertising, is characterized by its strong semiotic and affective nature. It is highly context specific and its economic value arises from its intangible character (Asheim/Coeen/Wang 2007). As such we consider it as less relevant for the maritime industries as defined by our sample.

3.2 Emerging proximities within knowledge creation

The literature on knowledge generation and innovation is closely related to Schumpeter's work on economic development (Schumpeter 1934). From a spatial perspective, the ability to produce and absorb knowledge is considered key to innovation and sustainable economic success. Moreover, the 'right' configuration of spatial and relational proximity is crucial for firms (Nooteboom 2000; de Jong/ Freel 2010; Schamp/Rentmeister/Lo 2004). Knowledge is variant in form and type that the transaction thereof is found to be dependent on a multitude of factors and proximity in particular (Boschma 2005). Physical proximity is given by short geographical distance and considered to catalyze knowledge transfer by increasing the likelihood of interaction (Eriksson 2011; Storper/ Venables 2004), other forms of proximity such as cognitive, institutional and organizational proximity are based on the relations of actors and consider to broaden the bandwidth of communication by sharing (Gertler 1995; Torre/ Rallet 2005; Boschma 2005). Cognitive proximity exists when actors share the same knowledge or technological base. Institutional proximity is realized by being a formal member of a club or association and finally organizational proximity is defined by being part of an overarching framework following same rules or strategies such as the subsidiaries within a company (Boschma 2005). With regard to the maritime economy we consider knowledge a multiplex subject including both advanced skills and standardized procedures with strong interrelation to physical goods and transportation.

The relational proximity prevailing by organizational, institutional and cognitive proximity is complementary to physical proximity in that it catalyzes the exchange of knowledge within a shared innovation process, knowledge base and competitive and regulatory dynamics (Pavitt 1984; Malerba 2005). Furthermore, the continuous interaction in the value added process, potentially creates a shared understanding and common interpretative schemes (Lam 2005) as well as knowledge sources which are complementary for the actors involved (Broekel/ Boschma 2010). Hence, complementarity in innovation capacity can be described as a temporal mentation or even completion of previous knowledge in order to achieve novelty.

The concept of related variety enables to understand the meaning of cognitive proximity for knowledge creation. Related variety is defined by *„sectors that are related in terms of shared or complementary competences“* (Boschma/Iammarino 2009: 292-293). Therefore, cognitive proximity between those sectors plays a crucial role. „Information is useless if it is not new, but it is also useless if it is so new that it cannot be understood" (Nooteboom 2000: 72). However, absorptive capacity is also constantly in flux. The number of employees and their knowledge base heavily affect a firm's capability to broker knowledge (Cohen/Levinthal 1990). Primarily, the concept of related variety focuses on technological development within manufacturing sectors. Service sectors are not explicitly taken into account in this concept. However, they are relevant in the maritime economy due to their constitution, in which shipping companies are a prime example for an actor linking the sector of transport and logistics, manufacturing and high tech, by commissioning the construction of vessels to a certain specification and inserting those direct or indirectly in the system of maritime transportation. Moreover, this parallel activity within two value chains makes the shipping companies and their trade organizations a centre of gravity for related services such as insurance, the acquisition of labor, standards and rules, which manifest the cognitive proximity between manufacturing and service sectors.

3.3 Knowledge in interaction and value added relations

Conceiving knowledge creation as a process implies interwoven and co-inciding patterns of development, production and placement of products and services. The synthesis is an evolving innovation system which, in the case of the maritime economy, is affected by technological change and restructuring of value chains.

To analyze this innovation system we focus on the patterns of proximity between the actors of the maritime economy and their functional relevance. Zillmer (2010) suggests an approach, which enables the analysis of knowledge in transfer. In her comprehensive analysis of different service activities she concludes on four different types generic activities related to the type of industrial cluster in question: high-tech, transformation services, transaction services and media/information services (Zillmer 2010). The focus is on the relational qualities between single actors rather than the inherent knowledge stock or the aggregated level of technological regimes. It assumes a non arbitrary selection of partners and distinguishes product and process related services (table 1). This approach is intrinsically relational since it implies that collaboration between the actors takes place for the purpose of knowledge generation. It also considers services and manufacturing activities as complementary in the value production (Bryson 2010).

	boat building	port corporation	port logistics	maritime services	maritime education and professional development	maritime science	marine engineering	marine engineering science	shipping companies	shipbuilding	shipping supplier	Other economic actors	Other science actors
boat building	high-tech												
port corporation	Transaction	Transaction											
port logistics	transaction	transaction	transaction										
maritime services	transaction	transaction	transaction	transaction									
maritime education and professional development	information	information	information	information	information								
maritime science	transformation	information	information	transformation	information	transformation							
marine engineering	transformation	information	information	transformation	information	transformation	high-tech						
marine engineering science	transformation	information	information	transformation	information	transformation	high-tech	transformation					
shipping companies	transaction	transaction	transaction	transaction	information	transaction	transaction	transaction	transaction				
shipbuilding	high-tech	transaction	transaction	transaction	information	transformation	transformation	transformation	transaction	high-tech			
shipping supplier	high-tech	transaction	transaction	transaction	information	transformation	transformation	transformation	transaction	high-tech	high-tech		
Other economic actors	n/a	n/a	n/a	n/a	information	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Other science actors	transformation	information	information	transformation	information	transformation	transformation	transformation	information	transformation	transformation	transformation	transformation

Table 1: the fields of activity in the maritime economy and types of knowledge in transfer (based on Zillmer 2010)

The concept defines transaction services as actors delivering input into the value chain process, which evolves around the amalgamation of different knowledge spheres. It focuses on the organization and management of economic transaction (Kujath/Schmidt 2010: 46) and includes advanced producer services such as insurances, financing or law, which are the backbone of the global economy.

Transformation services are provided by those actors who deliver their non-material input into material focused parts of the industry and thereby shape the product as such. This includes research and development facilities as much as consultants delivering input into for instance the high-tech industry. The focus is on the transformation of existing knowledge into new knowledge for the benefit of a different economic application (Kujath/Schmidt 2010: 46). The refinement of materials such as metal is strongly dependent on the research carried out by engineers. For example, the shape and consistency of ship hulls has been developed significantly due to new production processes in metal works and new materials. The results are plans or templates for wider series of production.

As a functional group high-tech actors are concerned with the production of material goods. The value added to the system is firmly resting thereon. As opposed to the former two groups the material input is valued at cost rather than in conjunction with non-material components. It revolves around the production of knowledge intensive material goods by integrating new knowledge in products and processes (Kujath/Schmidt 2010: 45). A typical high-tech product is the computer chip, which enables complex control techniques within maritime navigation or supply chain management. Since high-tech activities are defined by the invention of new products, transformation processes tend to refine these materials accordingly.

Finally, relations based on media and information services contain activities, which transform knowledge in standardized knowledge good. These are predominantly educational relations where guidance and instructions for action are provided. This type of knowledge is considered as a preparation for future experiences. For example masters and skippers of ships train their skills in simulators before employing in reality.

These four roles are applicable to the value chain activities of actors in the maritime economy in reference to the subsystem previously described and denoted in section 2. In order to explore distinct patterns of spatial organization, the following analysis applies three different methods to analyze the spatial configuration of the network of maritime actors in northern Germany based on the aforementioned theoretical framework.

4 Methodology

A multifaceted methodology is required in order to assess the heterogeneity in the maritime economy. Figure 1 shows the set-up of analysis as layered applications. The maritime economy crystallizes around port cities and port facilities and the extended hinterland. The geographical distribution of actors of the maritime economy forms the starting point of the analysis. We investigate the interrelations of actors of different fields of activity and focus on their functional means. Secondly, we show that the entire network of the maritime industry devolves into certain sub-networks, which can be set in relation to spatial qualities and sectorial composition. Thirdly, due to the fact that knowledge production is interlinked with the exchange and transformation of material goods in this sample we include value added characteristics in order to investigate the spatial range of actors. Thereby, the characteristics of value-added relations are being attributed to the network links. In other words, we consider the cooperation as being interlinked either with the transformation of goods or services, the transaction or the production and development of high-tech products.

[Insert figure 1 here]

Figure 1: set-up of the analysis as layered applications (own illustration)

The dataset used here results from large scale surveys in the maritime economy carried out by the Norddeutsche Landesbank – Regionalwirtschaft (Brandt/Dickow/Drangmeister 2010: 241-242). In an initial phase the database was built by gathering information from commercial resources, associations and networks, business directories as well as the Internet.

In a second step the actors were asked to name their partners, which they cooperate with for the purpose of (1) education and qualification, (2) temporal co-working on innovation oriented projects and (3) long-term strategic cooperation. In addition, the data contains structural indicators such as the firm size, employment, turnover, innovation activities and expenditures and ambitions in research and development. All in all, the network contains 1,873 actors and 4,174 network links.

5 Results

5.1 The maritime economy as an innovation system

The Social Network Analysis provides techniques to assess the importance and relations of individual actors. This bundle of methods is framed by a perception that “The structure of relations among actors and the location of individual actors in the network have important behavioral, perceptual, and attitudinal consequences both for the individual units and for the system as a whole” (Knoke/Kuklinsi 1982: 13). With regard to economic geography and spatial development, Ter Wal and Boschma (2009: 740) suggest that “networks are an appropriate conceptualization of inter-organizational interaction and knowledge flows.” This paper applies this relational approach in the context of knowledge networks in the maritime economy.

The network of the maritime economy revolves around a few actors as central nodes. Figure 2 shows the distribution of weighted degree centrality, which is the sum of links multiplied with their weights (Freeman 1979). This means that one actor with one triple weighted link is as important as an actor with three single linkages. Thus, high values of weighted degree centrality could be the result of a high number of low rated links or a lower number of highly classified connections.

The actors are ranked according to their weighted degree centrality. The slope begins at the value of 393 and decreases steeply. The second most connected actor has a weighted degree centrality of 272 followed by 266. Therefore, the slope is similar to a power decay function and may provide a scale-free network, which indicates that the network structure is independent form its size (Barabási 2009).

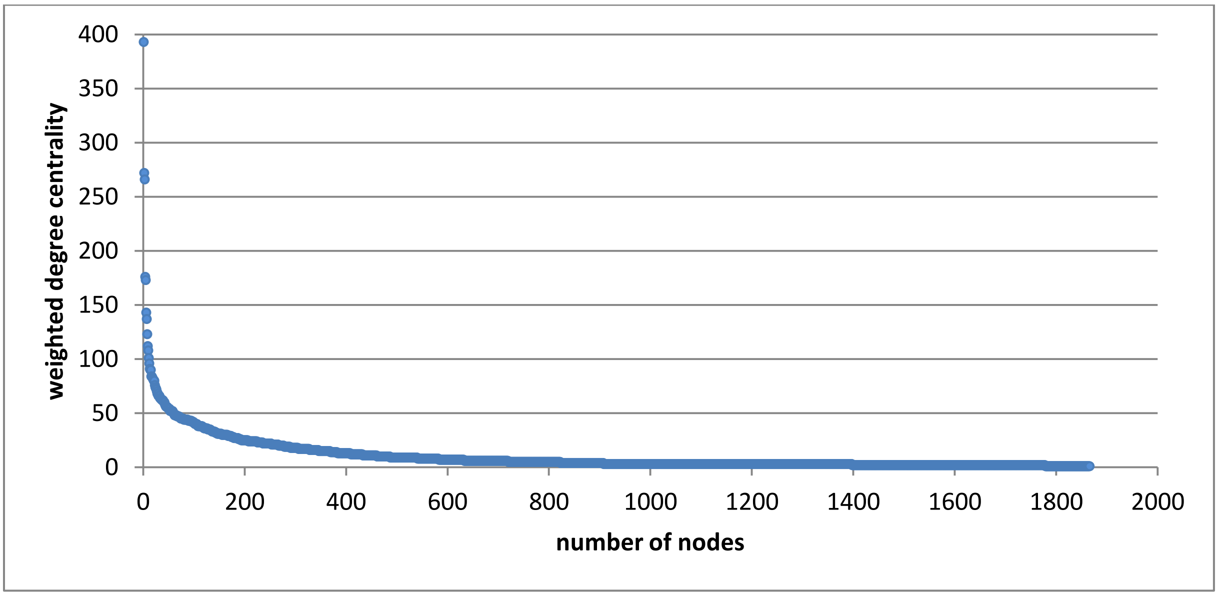

Fig. 2: Degree centrality distribution (own calculation)

Interestingly, among the top ten actors in terms of weighted degree centrality are five actors, which are classified as marine engeneering science and, therefore, act as public institutions. The most connected actor – Germanische Lloyd AG – provides maritime services in various fields. The Meyer Werft which operates in the field of ship building is ranked on sixth position. Followed by Hamburgische Schiffbau-Versuchsanstalt GmbH, providing expertise in marine engeneering and Briese Schiffahrts GmbH & Co. KG, operating as shipping company. The Hamburger Hafen und Logistik AG, which organizes and manages port activities within Hamburg - the biggest port of Germany - reaches the thirteenth highest value.

Figure 3 shows the entire network of the maritime economy. This graph was calculated in Gephi and the OpenOrd Algorithm was applied. This algorithm is based on the Frutcherman-Reingold algorithm, which has two guiding principles: vertices connected by an edge should be drawn near each other and vertices should not be drawn too close to each other (Fruchterman/Reingold 1991: 1131). Subsequently, the link between two nodes functions as an attraction force, whereas nodes without links repel each other. Since OrpenOrd displays a relational approach it highlights the subdivisions of the network by separating them visually. Thus, one can obtain a community structure of the network.

[Insert figure 3 here]

Figure 3: the entire network of the maritime economy. Circle size = degree centrality (own illustration)

Subsequently, economic change within the maritime economy might predominantly be driven by research institutions and a few more actors in maritime services and ship building, since these actors are the most connected and most dominant within this network, assuming that higher connectivity leads to more innovation and economic change. Furthermore these actors bridge different fields of activity and combine different knowledge bases.

5.2 Knowledge in interaction

The second step of the analysis considers the knowledge types 'in interaction'. The maritime economy transcends the sectors transport and storage, services and manufacturing. Therefore, by nature, value chains in the maritime economy integrate labor and material intensive processes as well non-physical processes, which draw exclusively on the skills and knowledge of workers. Thus, the application and generation of knowledge combines different activities ranging from practical experience to formalized and standardized procedures.

The most prominent knowledge types in the maritime economy are transaction and transformation processes representing 1,260 and 1,609 co-operations respectively. Furthermore, the network contains 626 high-tech relations and 301 information links. While transformation processes are based on explicit knowledge, transaction processes revolve around implicit knowledge sources. We expect that the spatial range of these networks is clearly different and that spatial proximity is more important for experienced based knowledge interaction. Figure 4 and 5 depict the spatial reach of transaction and transformation.

[Insert figure 4 and 5 here]

Fig. 4 and 5: Knowledge types in transfer: transaction (left) and transformation (right) links and their geographical range

The actors involved in transaction processes form three observable triangles. The first one is located between the cities of Hamburg, Bremen and Bremerhaven. To a large extent the "Alfred Wegener Institut", which is carrying out research in the fields of oceans, the atmosphere and climate change, forms this triangle. With a weighted degree centrality of 176 this research institute is the fourth best linked among all actors.

The second triangle draws on links between Hamburg, Leer and Papenburg. In this sub-network the Meyer Werft GmbH is dominant. Based on the number of links it has a degree centrality of 173. The Meyer Werft, therefore, is ranked fifth and establishes mostly transaction links to actors of port authorities and port logistics and maritime services. These actors tend to be concentrated in Hamburg around port facilities. Furthermore, shipowners are located in Leer and maintain co-operations with the Meyer Werft as well.

The third triangle is less striking in form. The actors of it are located in Hamburg, Papenburg and Emden. Emden hosts a high share of employment in high-tech branches (BBR 2011) and is, therefore strongly specialized in knowledge intensive manufacturing.

Interestingly, Hamburg functions as an anchor point for all these triangles, since it lies at the point of superimposition of the most intense edges. There are only a few cross-links between these triangles. This spatial pattern is an indication for an emerging 'nested hierarchy' (Camagni 1993) in which Hamburg captures the highest rank and acts like a hub. Bremen is a second-tier city in this system.

Actors located there tend to form links predominantly to Hamburg but also to a lesser extent to the aforementioned edges of the triangles.

Compared to the network of transformation processes spatial differences are evident. The amount of links in both cases is almost equal. However, actors operating with transactional knowledge tend to be more concentrated on a discrete number of cities. Above all Hamburg remains the most central position in this sub-network. The re-occurring triangle formed by Hamburg, Bremen and Bremerhaven suggests that these cities form an urban system with an hierarchical tendency.

5.3 Modular Network

In the third part of our analysis we investigate the interrelatedness of certain sub-networks based on the dominant form of knowledge. Small-worlds are sought to be detected by applying the algorithm of Newman (2006). These sub-networks indicate that the maritime economy consists of different parts which share intense linkages within and less intensive relations outside of these sub-divisions. It informs our understanding of the production of knowledge as a complex process in which services, manufacturing and qualification activities are interwoven. Moreover, we hypothesize that cognitive proximity is an important mechanism in shaping such sub-divisions of networks and therefore, modularity represents a certain degree of communality of the actors.

The modularity calculation indicates reliable results with a value of 0.584. The closer it is to 1 the clearer the communities are differentiated (Lambiotte/Delvenne/Barahona et al. 2009; Blondel 2008). The entire network of the maritime economy dissolves into 48 different modules, which differ clearly in terms of size and composition. See the appendix for further descriptive statistics.

In the following section, we focus on the five biggest modules in our data sample. In total, these contain 1,055 actors. These modules have more than 150 nodes and differ clearly in terms of functional composition and spatial ranges of their network links. Firstly, we discuss the functional composition, which is given by the fields of activity the actors belong to. In a second part of the analysis we will look at the spatial range of the modules.

Table 2 shows the quotient of specialization of each module. Values above 1 indicate that the module has a higher share in an activity field compared to the overall share of the whole sample. A Value below 1 indicates that the share of a field of activity is below the average. For instance module 1 - ship-building and suppliers - reaches a value of specialization in the field of shipping suppliers of 2.53 followed by shipbuilding with a value of 2.16 and maritime science with a value of 1.53. It is therefore containing a higher share of actors from these fields than the overall sample. Finally, the values for maritime education, professional development and marine engineering science are slightly above

1. Module 1 is strongly oriented towards manufacturing combined with engineering and qualifying tasks. In other words, this module represents the core of the cluster revolving around the production of ships in the maritime economy.

Module 2 - engineering and science - displays high values in the fields of maritime science, marine engineering and marine engineering science. In contrast to module 1, cooperation in module 2 is underpinned by research and development activities and is less production oriented. Module 3 – ports and education - is strongly specialized in maritime education and professional development and port logistics. Module 4 – ports and shipping - represents a community in which port corporation, port logistics and shipping companies maintain intense corporate networks. These fields of activity are supposed to require access to port facilities. Whether this holds true for the shipping companies will be investigated in a spatial assessment of these modules. Finally, module 5 – services and shipping - is strongly specialized in service activities ranging from education to maritime services, and displays high shares of shipbuilding and shipbuilding suppliers. Thus, this module is placed at the intersection of the services and the manufacturing parts of the maritime economy.

Module and main activities	**1 Shipbuilding and suppliers**	**2 Engineering and science**	**3 Ports and education**	**4 Ports and shipping**	**5 Services and shipping**
building	0,29	0,00	0,81	0,44	0,00
port corporation	0,10	0,63	**1,61**	**1,60**	0,56
port logistics	0,42	0,25	**2,88**	**1,77**	0,19
maritime services	0,82	0,26	**1,41**	**1,06**	**2,21**
maritime education and professional development	**1,10**	0,00	**3,12**	0,00	**1,99**
maritime science	**1,53**	**2,48**	0,96	0,52	0,31
marine engineering	0,73	**1,95**	0,19	0,55	0,15
marine engineering science	**1,03**	**2,51**	0,22	0,31	0,07
shipping companies	0,88	0,33	**1,20**	**1,31**	**1,96**
shipbuilding	**2,16**	0,16	**1,15**	0,84	**1,95**
shipping supplier	**2,53**	0,27	0,63	0,88	0,86
Other economic actors	0,55	**1,39**	**1,03**	**1,40**	0,89
Other science actors	0,97	**1,61**	0,49	0,96	0,63

Table 2: The five biggest modules and the quotient of specialization within fields of activity (own calculation)

A closer look on the types of knowledge interaction reveals an important characteristic in regards to the commonly used knowledge bases. As mentioned before knowledge production is a continuous process in which previous knowledge is expanded and complemented by new knowledge. Each actor is embedded in a professional context of knowledge, which determines in which form knowledge is appreciated, thus, accepted and accessible for further development. For instance scientific knowledge production is expressed in journal articles. These reflect previous literature and highlight own and new contributions to research. In contrast, knowledge production in engineering results in patents or plans. Knowledge generation in services tends to initiate new processes, which could not have been managed without it.

The analysis of modules indicates that there is a relation between the relational proximity of actors and their shared knowledge typologies in the sample. Each module shown in table 3 revolves around a distinct type of knowledge relation.

Module and main activities	**1 Ship-building and suppliers**	**2 Engineering and science**	**3 Ports and education**	**4 Ports and shipping**	**5 Services and ship-ping**
Types of knowledge relations within a module					
high-tech	16,0%	29,7%	1,6%	11,2%	1,3%
Transaction	30,0%	10,0%	65,6%	67,9%	87,9%
Transformation	53,1%	58,8%	17,0%	16,5%	6,0%
Information	0,8%	1,6%	15,8%	4,5%	4,7%
Number of links	*636*	*320*	*247*	*224*	*232*

Table 3: The five biggest modules and the type of knowledge involved (own calculation)

Module 1 - ship-building and suppliers - displays intense manufacturing activities. Knowledge here is predominantly produced by transformation process, since the share of transformation links within the module accounts for 53.1 %. Knowledge production correlates with the exchange of material goods. Furthermore, transaction links reach a share of 30.0 % as a result of intense knowledge relations between maritime sciences and ship builders and their suppliers. In other words, actors within this module potentially complement explicit knowledge applied in transformation processes with experience based knowledge in order to control and implement these transformation tasks (Niehues/Nissen/Reinhart 2012).

Module 2 - Engineering and science - is also specialized in manufacturing activities. Predominantly, the actors carry out engineering and science activities, but in contrast to the module 1 it focuses stronger on the development of new products, since high-tech relations with a share of 29.8 % are very significant. The modules 3 - ports and education and 4 - ports and shipping - are mainly formed by transaction links revolving around functions of port facilities. Moreover, links within module 3 are characterized by information relations and reach a share of 19.0 %. Contrastingly, module 4 is less specialized within port logistics and has a higher share of high-tech links then the former module. Thus, both modules have broad activities in services in common but differ clearly in terms of second-tier activities. Whereas, module 3 is oriented towards education and qualification, module 4 links services with high-tech activities. Finally, module 5 - services and shipping - is clearly defined by transaction links between maritime services, maritime education and professional development, shipping companies and shipbuilding. Thus, tacit knowledge plays an important role and is applied in a heterogeneous value chain ranging from education activities and services towards shipbuilding.

Finally, complementary specialized clusters tend to be organized in geographical proximity and capture a functional position within the urban system. This, in particular, holds true for modules revolving around transaction relations. Contrastingly, transformation based interrelations reach across the rest of Germany with a strong anchor point in the city of Hamburg.

6 Discussion

The multi-facetted set-up of the analysis involving visualization and quantitative methods enables us to understand the heterogeneous cluster of the maritime economy. The combination of knowledge creation and value-added relations characterizes the distinct qualities of the maritime economy. The transcendence of the sectors transportation and storage, manufacturing and services implies that actors for which knowledge is an important resource and actors relying on physical labor and land as production factors are interacting. In certain parts, there is a strong physical relation and interdependence with port facilities. The spatial development is highly intertwined with the evolution of transportation networks on the land- and seaside and thereby needs to be embedded in a global context.

Considering the maritime economy as an innovation system relates the discussion to technological and structural change and narrows it to those instances where the port and city remain to have synergies. This enables researchers in the fields of spatial sciences and economic development to clarify two mechanisms: firstly, in which context do port city development and waterfront regeneration happen? Secondly, where does this global context of knowledge expansion trickle down and forms the built environment? In the first part, we drew the picture of the maritime economy coming out of the sea and being fixed to port facilities. This metaphor illustrates that the activities of the maritime economy reach far beyond ship building and the provision of transportation. Vice versa it is not merely a development away from the traditional maritime trade and the manufacturing of vessels, but also a qualitative change within the entire economy. New actors have developed their competencies and oriented themselves towards the modern maritime economy. This, particularly, holds true for service firms, as they provide services not only for the maritime economy but also for other sub-systems in the entire economy.

7 Conclusion

The analysis shows three important findings for the maritime economy and its impact on spatial restructuring. Firstly, the network of the maritime economy is predominantly held together by actors of the maritime services, shipbuilders and research institutions. Thus, the network centers on advanced producer services, manufacturing and research institutions. This involves knowledge from transaction, high-tech and information and requires mediation between tacit and codified knowledge. Additionally, modules with a distinct specialization in ship building or engineering tasks emerge. Shipping companies have particularly high betweenness centralities and act as bridging actors between certain sub-divisions.

Secondly, conceiving knowledge as an interactive process, in which transaction, transformation, high-tech and information processes are carried out, deepens our understanding of cognitive and spatial proximity. Whereas spatial proximity is still crucial for experienced based learning, cognitive proximity becomes even more crucial in the context of globalization, since actors are able to expand their absorptive capacity. This interplay is important for the sustainable development of the maritime economy. Our empirical results reveal that the maritime economy revolves around certain knowledge bases and the cognitive proximity between the actors. A common sense of understanding and communicating new knowledge drives specialization in engineering and high-tech activities with strong tendencies towards local clustering and services spreading their networks in a regional spatial range. Moreover, the higher the share of implicit knowledge the closer are the networks centered on a core activity.

Thirdly, reflecting these findings with regard to the urban system in the northern part of Germany three constituting elements are to be found. The first one is centralized maritime services in main cities, particularly in Hamburg. These services are assumed to be attracted to urban qualities in which face-to-face contacts and high accessibility occur. Secondly, certain activities in manufacturing, such as shipbuilding and ship suppliers are concentrated in remote areas along the Ems axis. These actors strongly depend on the availability of highly qualified personnel. Since these actors are located in less dense areas geographical proximity seems to be less important to enable knowledge spillover. However, geographical proximity between shipbuilders and their suppliers is still necessary. This might be due to lower the risk of delays in just in time production or ad-hoc problem solving. Finally, as a third element of this urban system, bridging services such as shipping companies and research institutions emerge as actors connecting the production part and the service oriented activities of the maritime economy.

Further research is required to triangulate these findings with more qualitative methods in the context of the maritime industry. Also the specific role of shipping companies is worth exploring, as they are situated at the intersection of manufacturing and transport related value added processes. Furthermore, it would be worth applying this analysis to another industrial cluster in order to establish in how far the findings are transferable. Lastly, the existence and typology of distinct patterns of organization within the maritime economy, which we have traced in this research needs to be reflected in regards to the governance of value chains and territories.

8 References

Amin, A. and P. Cohendet (2004) *Architectures of knowledge. Firms, capabilities, and communities*. Oxford, New York: Oxford University Press.

Amin, A. and J. Roberts (2008) *Knowing in action: Beyond communities of practice*. In: Research Policy. 37, 353-369.

Asheim, B., L. Coenen and J. Vang (2007) *Face-to-Face, buzz, and knowledge bases: sociospatial implications for learning, innovation, and innovation policy*. In: Environment and Planning C: Government and Policy 25(5): 655-670.

Barabási, A.-L. (2009) *Scale-Free Networks: A Decade and Beyond*. In: Science. 325, 5939:412-413.

BBR, Bundesamt für Bauwesen und Raumordnung (2011) INKAR. Indikatoren und Karten zur Raum- und Stadtentwicklung. Bundesamt für Bauwesen und Raumordnung BBR, Bonn.

Bentlage, M., S. Lüthi and A. Thierstein (2013) *Knowledge Creation in German Agglomerations and Accessibility – An Approach involving Non-physical Connectivity.* In: Cities. 30, 1:47-58.

Blondel, V. D., J.-L. Guillaume, R. Lambiotte and E. Lefebvre (2008) *Fast unfolding of communities in large networks. In: Journal of Statistical Mechanics: Theory and Experiment*, http://perso.uclouvain.be/vincent.blondel/publications/08BG.pdf, 05.12.12.

Boschma, R. (2005) *Proximity and Innovation: A Critical Assessment.* In: Regional Studies. 39, 1:61-74.

Boschma, R. and S. Iammarino (2009) *Related Variety, Trade Linkages, and Regional Growth in Italy.* In: Economic Geography. 85, 3:289-311.

Brandt, A., C. M. Dickow and C. Drangmeister (2010) *Entwicklungspotenziale und Netzwerkbeziehungen maritimer Cluster in Deutschland.* In: Zeitschrift für Wirtschaftsgeographie. 54, 3-4:238-253.

Broekel, T. and R. Boschma (2010) *Aviation, Space or Aerospace? Exploring the knowledge networks of two industries in the Netherlands.* Philipps-Universität Marburg, Marburg.

Brown, E., B. Derudder, C. Parnreiter, W. Pelupessy, P. Taylor, and F. Witlox (2010) *World City Networks and Global Commodity Chains: towards a world-systems' integration*. In: Global Networks. 10, 1:12–34.

Brown, J. S. and P. Duguid (2002) *The Social Life of Information.* Boston: Harvard Business School Press.

Bryson, J. and P. Daniels (2010) *Service Worlds. The "Service Duality" and the Rise of the "Manuservice" Economy.* In: Maglio, P., Kieliszewski, C. and J. Spohrer (eds.), Handbook of Service Science,

Camagni, R. P. (1993) *From city hierarchy to city network: reflections about an emerging paradigm.* In: Lakshmanan, T.R. and P. Nijkamp (eds.), Structure and change in the space economy, Berlin, Heidelberg: Springer-Verlag, 66-87.

Cohen, W. M. and D. A. Levinthal (1990) *Absorptive capacity: A new perspective on learning and innovation.* In: Administrative Science Quarterly. 35, 1:128-152.

de Jong, J. and M. Freel (2010) *Absorptive capacity and the reach of collaboration in high technology small firms.* In: Research Policy. 39, 1:47-54.

Derudder, B. and F. Witlox (2010) *World Cities and Global Commodity Chains: an introduction.* In: Global Networks. 2010, 10:1–11.

Dicken, P. (2011) *Global Shift. Mapping the Changing Contours of the World Economy.* 6, London: SAGE.

Eriksson, R. H. (2011) *Localized Spillovers and Knowledge Flows: How Does Proximity Influence the Performance of Plants?* In: Economic Geography. 87, 2:127-152.

Eurostat (2008) *NACE Rev. 2. Statistical classification of economic activites in the European Community.* Methodologies and Working papers, Luxemburg: Office for Official Publications of the European Communities.

Gertler, M. S. (1995) *"Being there": Proximity, Organization, and Culture in the Development on of Advanced Manufacturing Technologies.* In: Economic geography. 71, 1:1-26.

Gertler, M. S. (2003) *Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there).* In: Journal of Economic Geography. 3, 1:75-99.

Gertler, M. S. (2008) *Buzz Without Being There? - Communities of Practice in Context*. In: Amin, A. and J. Roberts (eds.), *Community, Economic Creativity, and Organization*, Oxford: 203-226.

Growe, A. (2012) *Raummuster unterschiedlicher Wissensformen. Der Einfluss von Transaktionskosten auf Konzentrationsprozesse wissensintensiver Dienstleister im deutschen Städtesystem.* In: Raumforschung und Raumordnung. 2012, 70:175-190.

Hall, A. (2007) *Tätigkeiten und berufliche Anforderungen in wissensintensiven Berufen. Empirische Befunde auf Basis der BIBB/BAuA-Erwerbstätigenbefragung 2006. Gutachten im Rahmen der Berichterstattung zur technologischen Leistungsfähigkeit Deutschlands.* Bundesinstitut für Berufsbildung, Bonn.

Hall, P. V. (2007) *Delineating urban territories. Is this a relevant issue?* In: Cattan, N. (eds.), Cities and networks in Europe. A critical approach of polycentrism, Paris: John Libbey Eurotext, 3-14.

Hall, P. V. (2007) *Seaports, Urban Sustainability, and Paradigm Shift.* In: Journal of Urban Technology. 14, 2:87–101.

Hall, P. V., and W. Jacobs (2012) *Why are maritime ports (still) urban, and why should policy-makers care?* In: Maritime Policy & Management: The flagship journal of international shipping and port research. 39, 2:189-206.

Hein, C. (2011) *Port Cities: Dynamic Landscapes and Global Networks.* London: Routledge.

Hesse, M. (2010) *Cities, material flows and the geography of spatial interaction: urban places in the system of chains.* In: Global Networks. 2010, 10:75–91.

Jacobs, W., C. Ducruet, and P. De Langen (2010) *Integrating World Cities into Production Networks: the Case of Port Cities*. In: Global Networks. 2010, 10:92–113.

Jacobs, W., H. Koster and P. Hall (2010) *The Location and Global Network Structure of Maritime Advanced Producer Services.* In: Urban Studies. 21, 2-21.

Knoke, David, and James H. Kuklinski (1982) *Network Analysis*. Beverly Hills: Sage.

Kujath, H.-J. and S. Schmidt (2010) *Wissensökonomie.* In: Kujath, H.J. and S. Zillmer (eds.), Räume der Wissensökonomie. Implikationen für das deutsche Städtesystem, Stadt- und Regionalwissenschaften, Urban and Regional Sciences, 6, Münster: Lit Verlag, 37-50.

Lambiotte, R., J.-C. Delvenne, and M. Barahona (2009) *Laplacian Dynamics and Multiscale Modular Structure in Networks.* In: Journal of Statistical Mechanics: Theory and Experiment, 05.12.12.

Lam, A. (2005) *Organizational Innovation.* In: Fagerberg, J., D. C. Mowery and R. R. Nelson (eds.), The Oxford Handbook of Innovation, New York: Oxford University Press, 115-147.

Legler, H. and R. Frietsch (2006) *Neuabgrenzung der Wissenswirtschaft – forschungsintensive Industrien und wissensintensive Dienstleistungen (NIW/ISI-Listen 2006).* Niedersächsisches Institut für Wirtschaftsforschung, Fraunhofer-Institut für System- und Innovationsforschung, Hannover, Karlsruhe.

Malerba, F. (2005) *Innovation and the Evolution of Industries.* Centro di Ricerca sui Processi di Innovazione e Internazionalizzazione, Mailand.

Newman, M. E. J. (2006) *Modularity and community structure in networks.* In: PNAS. 103, 23:8577–8582.

Niehues, M., F. Nissen and G. Reinhart (2012) *Moderne Werkstattfertigung. Effiziente Fertigung hochvarianter Produkte durch Echtzeitortung und adaptive Steuerung der Auftragsreihenfolge mittels bionischer Algorithmen*. In: Zeitschrift für wirtschaftlichen Fabrikbetrieb. 107, 12:892-896.

Nooteboom, B. (2000) *Learning by Interaction: Absorptive Capacity, Cognitive Distance and Governance.* In: Journal of Management and Governance. 4, 69-92.

Notteboom, T. and J. Rodrigue (2005) *Port Regionalization: Towards a New Phase in Port Development.* In: Maritime Policy and Management. 32, 3:297-313.

Pavitt, K. (1984) *Sectoral patterns of technical change: Towards a taxonomy and a theory.* In: Research Policy. 13, 6:343-373.

Podolny, J. M. (2001) *Networks as the pipes and prisms of the market.* In: The American Journal of Sociology. 107, 1:33-60.

Polanyi, M. (1966) *The tacit dimension.* London: Routledge & Kegan Paul.

Rodrigue, J.-P. (2013) *Transportation, Globalization and International Trade.* 3, New York: Routledge.

Schamp, E. W., B. Rentmeister and V. Lo (2004) *Dimensions of Proximity in Knowledge-based Networks: The Cases of Investment Banking and Automobile Design.* In: European Planning Studies. 12, 5:607-624.

Schubert, D. (2009) *Stürmische Zeiten für die nordwestdeutschen Seehafenstädte.* In: RaumPlanung. 2009, 146:199-204.

Schumpeter, J. A. (1934) *The Theory of Economic Development.* 1, London: Humphrey Milford.

Simmie, J. (2004) *Innovation and Clustering in the Globalised International Economy.* In: Urban Studies. 41, 5/6:1095-1112.

Storper, M. and A. J. Venables (2004) *Buzz: Face-to-Face contact and the Urban Economy.* In: Journal of Economic Geography. 4, 4:351-370.

Ter Wal, A. L. J., and R. A. Boschma (2009) *Applying social network analysis in economic geography: framing some key analytic issues*. In: The Annals of Regional Science. 43, 3:739-756.

Thomi, W. and R. Sternberg (2008) *Editorial: Cluster – zur Dynamik von Begrifflichkeiten und Konzeptionen.* In: Zeitschrift für Wirtschaftsgeographie. 52, 2/3:73-78.

Torre, A. and A. Rallet (2005) *Proximity and Localization.* In: Regional Studies. 39, 1:47-59.

Zillmer, S. (2010) *Teilsysteme und Operationalisierung der Wissensöknomie.* In: H.–J. Kujath and S. Zillmer (eds.), Räume der Wissensökonomie. Implikationen für das deutsche Städtesystem, Stadt- und Regionalwissenschaften, Urban and Regional Sciences, 6, Münster: Lit Verlag, 105-129.

Appendix:

Selection of network parameters and structural indicators of the modules 2, 13, 29, 35 and 43

			module				
variable		**scale**	**2**	**13**	**29**	**35**	**43**
Number of actors			**157**	**183**	**200**	**232**	**283**
Degree Centrality		mean	4.54	4.42	4.00	4.47	6.91
Closeness Centrality		mean	0.11	0.12	0.09	0.09	0.10
Betweenness Cen-trality		mean	0.00	0.00	0.00	0.00	0.00
Export ratio		mean	27.23	17.79	25.95	29.68	38.42
Employment		mean	63.81	301.96	380.42	39.69	426.94
Did your company carry out Research and development within the years 2005 and 3008?	yes, continuously	share	18.60	12.24	25.00	43.59	51.16
	yes, continuously	count	8.00	6.00	12.00	17.00	44.00
	yes, occasionally	count	9.00	6.00	8.00	11.00	14.00
	no	count	26.00	37.00	28.00	11.00	28.00
How high were the expenditures for R&D?		mean	3.33	1.66	3.27	20.65	5.15
R&D employment		mean	2.64	2.68	6.32	2.68	14.14
Did you company realize innovation in terms of products or processes?	yes	share	63.16	64.29	70.73	83.33	81.93
	yes	count	24.00	27.00	29.00	30.00	68.00
	no	count	14.00	15.00	12.00	6.00	15.00