Subsidiaries' local embeddedness, brokerage and innovation outcomes: A network perspective.

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ABSTRACT

Many scholars conceptualize the MNC as an intraorganizational network in which the subsidiaries occupy a bridging position between the MNC and local external networks (Almeida, Song, & Grant 2002; Andersson, Forsgren, & Holm 2002). Through the embeddedness in local networks, subsidiaries can tap into heterogeneous resource and capability pools and, thus, develop knowledge together with their local network partners (Andersson et al. 2002; Bartlett and Ghoshal 1990). This study explores subsidiaries' local network embeddedness and how it contributes to localized subsidiary innovation output from a social network perspective. In particular, we are interested in analyzing the consequences of local network density, diversity and, subsidiaries network position on its innovation outcomes. Data are derived from a longitudinal quantitative study of the entire R&D network within one of the largest lifescience cluster in Germany. The findings of our count model indicate that the most valuable innovation driver with regard to the structure of the regional network is the size (density) of the local network. With regard to the network position, our findings indicate that a strong brokerage position has a significant positive influence on the innovation output while a position in the core of the network has a significant negative effect on the innovation output. Our results shed new light on the relationship between local embeddedness, brokerage, the danger of overembeddedness and innovation output.

1. INTRODUCTION

Starting with Hymer (1960), for a long time the raison d'être of multinational companies (MNC´s) was viewed in its ability to transfer and exploit proprietary advantages developed in the home country (Buckley and Casson 1976; Hymer 1960). However, with the growing awareness that knowledge is a key source of competitive advantage and that competencies developed locally can be utilized for the advantages of the multinational firm as a whole, the focus has shifted to the role of subsidiaries for the innovation process of the whole MNC. Expansion in foreign markets provides MNC´s not only with ways to exploit firm specific advantages, but also with means to tap into subsidiaries local skills and resources, develop new knowledge and to explore new capabilities that enhance competitiveness (Ghoshal 1987; Lu and Beamish 2004; Madhok 1997).

Within this context some scholars frame the multinational corporation as a geographically dispersed organization in which each geographical unit is a node in a local network. Each node possesses knowledge, capabilities and, relationships with local actors that are a source of the competitive advantage of the MNC as a whole (Forsgren 2008). Due to the fact that high-value knowledge increasingly is geographically dispersed (Kuemmerle 1997), the competitiveness of the MNCs is thus becoming more dependent on its ability to establish a presence at multiple locations to access innovation networks of new knowledge and capabilities.

Against this background, international strategy researchers argue that MNC´s seek specific locations to access valuable idiosyncratic knowledge and generate innovations (Kogut and Zander 1993; Porter 2000; Shaver, Mitchell, & Yeung 1997; Tallman, Jenkins, & Pinch 2004). By selecting specific industry clusters for subsidiary location, MNC´s access knowledge that is idiosyncratic to those locations and may obtain a knowledge-based competitive advantage over firms that are not in the cluster (Maskell 2001). Scholars in the field of strategy are also increasingly studying location as a determinant of competitive advantage of firms (Bell 2005; Bell, Tracey, & Heide 2009; Canina, Enz, & Harrison 2005) with particular attention paid to the role of geographical clusters as an environment for MNC subsidiaries (Birkinshaw and Hood 2000; Porter 1990; Tallman et al. 2004). Firms based in such local or regional agglomerations are shown to benefit from locating in clusters as they outperform those not located in clusters (Baptista and Swann 1998; McCann and Folta 2008).

Observing that an important factor determining a subsidiaries innovative performance is its local R&D collaboration network, recent research shifted its focus of attention from analyzing local agglomeration effects in clusters towards recognizing the increasing embeddedness of subsidiaries in local R&D or production networks. In particular, in rapidly evolving sectors where the locus of proprietary knowledge is dispersed across firms and quickly shifts over time, the pooling of resources through joint R&D can lead to faster and higher-impact technological development, as opposed to internal development (Doz and Hamel 1998). As a result, in knowledge-intensive industries such as life science the subsidiaries local research-network facilitates sharing and transfer of patentable technical knowledge, given its embedded business relationships (Forsgren, Holm, & Johanson 2005). As the life-science industry is highly dependent upon a complex and evolving scientific research base (Pisano 20006), in particular pharmaceutical MNC´s have been increasingly relying on biotechnology for their R&D activities (Giesecke 2000: 208).

Despite the growing awareness of the benefits of local network embeddedness of foreign subsidiaries only sparse research so far has examined characteristics of the local network, and characteristics of the subsidiaries position within that network, utilizing techniques of social network analysis. In this paper we focus on German subsidiaries of global pharmaceutical MNC´s who are located in the “Biotechnologie-Cluster Rhein-Neckar”. From a network structure perspective, we analyze the influence of the size (density) and diversity of the R&D-network on the innovation output of the subsidiaries located within that cluster. We also analyze the embeddedness of the MNC’s-subsidiaries within this regional network. In particular we study the MNC’s-subsidiaries brokerage function and their position in the network core (K-core position). We formulate four hypotheses linking the local R&D network characteristics and the subsidiaries network position to the innovative success of these subsidiaries. Our findings indicate that a strong brokerage position has a significant positive influence on the innovation output while a core position has a significant negative influence on the innovation output.

2. THEORY

The host country has been proven to be important to MNC subsidiaries, either in their operations, as a knowledge source (Manolopoulos, Papanastassiou, & Pearce 2007), for subsidiaries’ knowledge creation and innovation (Almeida and Phene 2004; Frost 2001; Phene and Almeida 2008), internal legitimacy (Hillman and Wan 2005) and beneficial knowledge spillovers (Singh 2005). However, the host country has received less than deserved attention within the International Management (IM) research, set up in a social network perspective of the MNC subsidiaries.

Our framework to explain subsidiaries’ local embeddedness within host country networks on innovation output is grounded on the knowledge leveraging model of the MNC (Grant, Almeida, & Song 2000), learning and knowledge-based theories (March 1991; Spender and Grant 1996), the social network perspective (McEvily and Marcus 2005; Nahapiet and Ghoshal 1998), and the theory of the MNC as a differentiated network (Nohria and Ghoshal 1997). In the next sections we will further elaborate these issues. In doing so, we first discuss the concept of innovative output, and then turn our attention to the role of external network linkages for the innovative output of the MNC subsidiaries. We then develop our hypotheses and discuss our first results.

2.1 Innovation and the recombination of knowledge

The idea that innovation arises from the recombination of existing and new knowledge is well established within the knowledge leveraging model of the MNC (Bartlett and Ghoshal 2002; Grant et al. 2000) and more broader the knowledge based view of the firm (Grant 1996; Spender 1996). In this context, innovation is seen as an outcome of a process involving the development, diffusion and application of knowledge embedded within particular social and institutional contexts (McLoughlin 1999; Van de Ven 1986). As a consequence, it is important for a MNC to sustain its innovative competencies by constantly upgrading its knowledge base (Acs and Audretsch 1990; Dosi 1988; Iansiti and Clark 1994; March 1991; Spender 1996). Several studies have emphasized the critical function of accessing knowledge from external sources such as networks for innovation (Baptista et al. 1998; DeCarolis and Deeds 1999; Kogut and Zander 1992; Saxenian 1990). So far, however, only sparse research has been conducted linking characteristics of the local network to the innovative performance of a MNC´s subsidiaries.

2.2 Patents as an indicator of the innovative capabilities of subsidiaries

In this study we utilize the innovation output through the patenting activities of MNC´s subsidiaries because patents are a critical measure of innovation output for firms especially in knowledge intensive industries (Ahuja 2000; Almeida and Kogut 1999; DeCarolis et al. 1999; Rosenkopf and Nerkar 2001; Sorensen and Stuart 2000). Whereas there seems to be no or only small effects of patents for securing the returns to innovation in industries such as manufacturing, semiconductor or communication equipment, patents are featured in drugs and medical equipment industries, pharmaceuticals and biotechnology (Ahuja 2000; Cohen 2005; Cohen, Nelson, & Walsh 2000; Hall 2005). In these industries patents can be considered not only as an indicator of a firm's innovative success, but also as a reasonable measure of a firm's innovative capabilities (Ahuja 2000; DeCarolis et al. 1999; Lerner 1994; see for example Powell, Koput, & Smith-Doerr 1996). Patents are formalized, codified and explicit manifestations of innovative ideas, products or processes, and embody a firm's technological and innovative knowledge. Even more so, patents granted represent successful outcomes of a highly uncertain research and development process (Dierickx and Cool 1989; Hagedoorn, Link, & Vonortas 2000; Powell et al. 1996). Framed in this context, patents are the visible (tacit) outcome of what March (1991) calls "explorative" learning (Forti and Toschi 2009; March 1991). Patent measures are particularly appropriate for testing assumption that include learning and knowledge creation because one of the requirements for patenting is novelty (Forti et al. 2009). Each time an new patent is created and worth to apply for, the organization has created something new or at least something that can be used in a different context than before. Thus, each new patent can be used as an approximation of innovation output.

2.3 External knowledge access and innovative capabilities of subsidiaries

We hypothesize that local network embeddedness in the host country will foster the development of a subsidiaries innovative capabilities, which in turn, will increase its innovation output in the form of patents. We draw upon prior research within the knowledge-based view demonstrating that the development of a firms innovative capabilities can be enhanced by its ability to access external flows of knowledge (DeCarolis et al. 1999). By accessing external knowledge firms can build capabilities in integrating and recombining the various components of their knowledge stock to develop new knowledge and innovations (Henderson and Cockburn 1994; Kogut et al. 1992; Teece 1994). However, while it seems obvious that a firms internal innovative capabilities correspond with the output of the innovation process, i.e. new products or patentable innovations, we want to discuss the mechanisms translating external knowledge into patenting activity. There are several mechanisms linking outside sources of knowledge to the speed of the innovation process (March and Simon 1958: 188; von Hippel 1998) that we will discuss below.

The first and most important one lies in the concept of absorptive capacity, a firm's ability ”to recognize the value of new information, assimilate it, and apply it to commercial ends” (Cohen and Levinthal 1990: 128). Absorptive capacity enables firms to better recognize and access external technological developments and external information, evaluate them and integrate them faster into its own innovation process. Absorptive capacity speeds up the innovation process by enabling the organization to make novel linkages between prior and new knowledge and to better incorporate external knowledge into new products and processes amendable to patenting (Cohen et al. 1990: 131).

There are additional mechanisms for external knowledge linkages to accelerate the innovation process. Knowledge from external linkages can increase a firm's openness to its environment and stimulate internal innovativeness (Hagedoorn 1993; Terpstra and Simonin 1993). In fact, Teece has argued that “to be successful, innovating organizations must form linkages upstream and downstream, lateral and horizontal” (Teece 1992: 22). External linkages raise a firms awareness of where useful complementary expertise resides outside the organization. This sort of knowledge can be knowledge of who knows what, who can help with what problem, or who can exploit new information (Cohen et al. 1990). External linkages will permit the firm to better understand and therefore faster evaluate the importance of external technological advances that provide signals as to the eventual merit of its own technological development efforts (Deeds, DeCarolis, & Coombs 1999). The firm is therefore getting valuable feedback to evaluate its own technological position and the potentials of its own innovative efforts. Such feedback will increase the firm´s agility to adjust its own research agenda, and concentrate on those research projects that are most successful and eliminate those that are risky.

Taking together, external linkages thus provide firms with background knowledge that would permit them to exploit rapidly useful scientific and technological knowledge through their own innovations or to be able to respond more quickly to competitors moves, in both cases improving their innovation speed. In particular, embeddedness in R&D-networks has been proven to be beneficial for innovation output (Deeds et al. 1999: 218; Maurer and Ebers 2006; Shan, Walker, & Kogut 1994; von Hippel 1998). Moreover, empirical evidence has shown that the relationship between embeddedness and innovation can be found in industries as diverse as chemicals (Ahuja 2000), biotechnology (Powell et al. 1996), textiles (Uzzi 1997a) or computers (Hagedoorn 2002).

Yet, how is network embeddedness related to the exploration of new knowledge? (Gilsing, Nooteboom, Vanhaverbeke, Duysters, & Van den Oord 2008). While an emphasis has been placed on the role of alliances and networks as a channel for diffusion of existing information and knowledge, the function of networks for exploration, has largely been ignored (Gilsing et al. 2008: 1718). Exploration is related to breaking away from the established way of doing things, with a focus on “the discovery and experimentation of new technologies” (Gilsing et al. 2008: 1718; March 1991; March 1994). Extending these thoughts, we investigate the interplay between network embeddedness and the creation and exploration of new knowledge, while building upon international strategy research arguing that MNC´s seek specific locations to access valuable idiosyncratic knowledge to generate innovations (Kogut et al. 1993; Porter 2000; Shaver et al. 1997; Tallman et al. 2004).

3. RESEARCH SETTING

Our research setting is the German lifescience industry and more specifically the biotechnology sector within that industry. Our unit of analysis are the German subsidiaries of global pharmaceutical MNC´s. We analyze the embeddedeness of these subsidiaries within the "Biotechnologie-Cluster Rhein-Neckar"-region, which is one of the largest life science cluster in Germany with regard to the proportion of pharmaceutical and chemical subsidiaries to biotech firms located in the cluster. Thus, the German "Biotechnologie-Cluster Rhein-Neckar"-region is an interesting setting as it reflects a young, upcoming and resource rich local environment for multinational subsidiaries to source knowledge and gain early access to scientific breakthroughs. Although German lifescience and the biotechnology industry in particular has been hampered by a hostile regulatory environment for genetic research throughout the 1980s and early 1990s, and facing additional institutional constraints (Casper 2007; Dohse 2000; Giesecke 2000; Kaiser and Prange 2004), it has grown and gained international significance since the mid 90s. The reason for this positive development can be traced back to the German government introducing a series of new technology policies designed to orchestrate the development of innovative technologies and small business start-ups (Casper 2007; Dohse 2000; Ernst & Young 2003; Giesecke 2000; Kaiser et al. 2004). This and other institutional changes have lead to a dramatic increase in growth rates for German biotech start-ups, and to a pronounced spatial clustering of the industry. Over the last five years, more than 500 new biotechnology start-ups have been founded in Germany, most of them located in clusters around universities and public research institutes (BIOCOM AG 2009). Actually, there are 531 German dedicated biotechnology firms in existence in Germany (Biotechnologie.de 2010).

4. HYPOTHESES

Our hypotheses focus on global pharmaceuticals subsidiaries embeddedness in the local R&D network and their influence on the innovative output. We base our hypotheses on two dimensions of a subsidiaries' local embeddedness that will be introduced in the subsequent discussion: characteristics of the local R&D-network itself and characteristics of subsidiaries position within the local R&D network.

4.1 Influence of local networks characteristics on knowledge access of subsidiaries

The importance of regional networks for firms strategies and outcomes has been emphasized by scholars following a variety of research traditions, most prominent regional economics (Baptista et al. 1998; Krugman 1991; Pounder and St.John 1996) strategy and international management (Andersson et al. 2002; Forsgren et al. 2005; Porter 1998), and social network research within organization theory (Ahuja 2000; Gulati 1998; Powell et al. 1996; Whittington, Owen-Smith, & Powell 2009).

Starting point for most discussions of regional networks is a large body of research pointing to the economic benefits of regional clustering (Krugman 1991; Porter 1998; Pounder et al. 1996). In particular for knowledge intensive industries, such as biotechnology, the importance of local clusters has been emphasized within the literature (Audretsch and Feldmann 1996; Baptista et al. 1998; DeCarolis et al. 1999; McKelvey, Håkan, & Riccaboni 2003). The most broadly discussed effect of close proximity is knowledge spillovers. Prior research has indicated that the munificence, the density and structural diversity of a particular local cluster has positive effects on the patenting rate of firms in knowledge intensive industries. Prior research has however also realized that the perspective of collocating firms within a cluster is not sufficient to explain the benefits regional agglomerations offer. The perspective has thus shifted on analyzing regional networks. This shift is driven by the observation that a key feature of successful regional clusters is related to the high level of embeddedness of local firms in a thick network of knowledge and information sharing, which is supported by close social interactions and by institutions building trust and encouraging informal exchanges among parties (Breschi and Malerba 2001). Embeddedness thus refers to the fact that economic behavior is affected by the industry constituents' dyadic social relations and the structure of the overall network of social relations. This is a crucial feature that is almost invariably associated with effectively functioning clusters.

Similarly, prior research in international management has acknowledged that the possibility for subsidiaries to tap into the body of localized knowledge and capabilities, depends critically on the ability to establish and maintain effective linkages and connections with other members of the local environment (Almeida et al. 2004; Frost 2001; Phene et al. 2008). However, subsidiaries' embeddedness in R&D networks in the host country has received limited mentions in the IM literature, and existing ones focused on business network or technical embeddedness (Andersson and Forsgren 1996; Andersson, Forsgren, & Holm 2007; Andersson, Forsgren, & Pedersen 2001). In addition, limited attempts have been made to move beyond an empirically vague appreciation of the performance implications and magnitude of the 'network effect' within geographical clusters and analyze characteristics of the local network in greater detail.

Our first hypotheses concentrate on two characteristics of the local R&D network a subsidiary is embedded in: the size of the network, and the diversity of the network in terms of the diversity of organizational types. The size of the local network, either measured by the number of ties or the number of nodes or as a proportion measured with the density of ties, can be attributed with a larger reservoir of valuable knowledge the local subsidiary can tap into. The larger the network, the larger the potential knowledge flow, and the higher the probability that localized subsidiary innovation in the form of patents occur. However, we do not expect that this effect is linear over time (Carroll and Hannan 1989). We expect that the advantages of the density show a marginally declining effect over time. After the density has reached a specific threshold, we do not expect the same magnitude of influence to continue. In fact Gilsing et. al (2008) argue and find significant support for their hypothesis that exploration is an inverse-U shaped function of density (Gilsing et al. 2008: 1727). These authors argue that the while density supports "the build-up of shared absorptive capacity it impede the possibilities for search and novelty creation" (Gilsing et al. 2008: 1727). We therefore state:

H1: The density of the local host country R&D network will have an inverse-U shaped effect on the foreign subsidiaries patent rate.

Aside from the network density, the diversity of network members is assumed to influence the potential knowledge flow to the subsidiary. Prior research has explored that local R&D networks in life-science are comprised of a variety of members, such as local pharmaceutical subsidiaries, local biotech firms, local universities and research institutes, and supporting organizations such as venture capitalist or IT providers (Powell et al. 1996; Powell, White, Koput, & Owen-Smith 2005; Whittington et al. 2009). With regard to universities and research institutes we assume that these organizations have regional expertise in certain areas of basic sciences as seen in their inputs (e.g. public and private investments in research) and outputs (e.g. scientific publications and skilled labor). These organizations offer valuable research collaborations with firms in the area, supply consulting services and often have expensive instrumentation and facilities other firms may require but cannot afford. Furthermore, they are considered key actors in the technology transfer process through out-licensing to firms and fostering firm founding via spin-offs (Cooper and Folta 2000; Gertler 2005).

Besides these beneficial knowledge transfer effects from research institutes and universities, there are additional sources of knowledge a regional network offers (Deeds et al., 1999).

For example, Gertler and colleagues (Gertler 2005; Quach and Gertler 2005) and Salazar and Holbrook (2003) and Holbrook and Salazar (2004) observed in their studies of Canadian biotechnology clusters that the presence of venture capital served as an important pool of valuable and location-specific knowledge (Holbrook and Salazar 2004; Salazar and Holbrook 2003). Firm growth benefited from business intelligence in terms of business planning, strategy formulation and coaching. Venture capitalists also facilitated networking for firms by identifying promising licensing opportunities and potential financial partners or by acting as a communication channel for local firms. These networks will provide feedback to local subsidiaries to evaluate and adjust their research agenda and to optimize their technological development efforts, thus increasing the patenting rate. In other studies knowledge spillovers did also arise from consulting firms and civic associations such as biotechnology initiatives (Asheim 2002). The accumulated experience and knowledge of these organizations creates a stock of valuable knowledge the subsidiary can access.

From a knowledge based point of view there are several reasons for the positive effects of knowledge diversity. Firms tend to search for new knowledge in the neighbourhood of their current technological knowledge domain (Nelson and Winter 1982). However, purely technologically local search restricts the possibilities for innovation through recombination, since it restricts the acquisition of novel and more distant knowledge (Leonard-Barton 1995; Levitt and March 1988). Firms must move beyond technologically local search to compete successfully over time (McGrath 2001; Rosenkopf et al. 2001). When innovating, the existence of heterogeneous knowledge enriches the possibility of new combinations and thus enhances the likelihood of emergence of novel ideas (Henderson and Cockburn 1996; Turner and Fauconnier 1997). Hence, it is not just the amount of knowledge that is accessed but the diversity of knowledge available to the subsidiary that will influence the patenting rate by altering the opportunities for new knowledge creation. Taking together, we hypothesize that the diversity of different types of organizations within the local clusters network will enhance a foreign subsidiaries' patenting rate.

Hypothesis 2. The structural diversity of the local host country R&D network will have a positive effect on the foreign subsidiaries patent rate.

4.2 Influence of network position on knowledge access of subsidiaries

Our second set of hypotheses concentrates on a subsidiaries position within the local R&D network. Several scholars have studied the relationship between a firm's research ties and its innovative performance (Baum, Calabrese, & Silverman 2000; Deeds and Hill 1996; Kotabe and Swan 1995; Lerner, Shane, & Tsai 2003; Shan et al. 1994). The research has established a link between a firm's research ties and various indicators of innovative performance, such as patenting propensity (Baum et al. 2000; Shan et al. 1994), level of product innovativeness (Kotabe et al. 1995), products under development (Deeds et al. 1996), and milestone stages reached (Lerner et al. 2003). In knowledge intensive industries research ties may lead to the codification of new knowledge through patenting. In the biotechnology industry, for example, collaborations are motivated by a desire to acquire basic knowledge that can be used to create novel molecular entities which are then patented, before they are entered into the development and regulatory process (Rothaermel and Deeds 2004: 202).

There are several reasons for this influence. Research ties influence innovation through the creation of trust and reciprocity exchanges (Granovetter 1992; Liebeskind 1996) that encourage knowledge sharing and collaboration, the generation of alternative perspectives on research problems and solutions (Dyer and Singh 1998; Powell et al. 1996), and the identification of appropriate referrals to locate new knowledge (Dyer and Nobeoka 2000; Rogers and Larsen 1984). Research ties stimulate the development of innovative capabilities and speed up the internal innovation process, thus increasing the rate of patenting (Powell and Brantley

1992: 371). Yet, more recently the focus of research has also shifted from analyzing the network membership in itself as a sufficient conditions for network benefits towards analysis of the position firms occupy within networks (Whittington et al. 2009). We build on these work and state that the examination of a subsidiaries *structural network position* provides valuable insights into the potential access it has to obtain and exchange knowledge, and on the speed in which the subsidiaries can transform this knowledge into patentable innovations (Podolny and Stuart 1995). I

In general there are two other different types of structural embeddedness in the literature and their functions have different effects on the innovation output of firms. The first one is Coleman's (1988) closure argument and the second one is Burt's (1992) structure hole argument (Burt 1992; Coleman 1988). Burt's work on structural holes is influential for developing the concept of brokerage (Burt 1992; Burt 1997; Burt 2003; Burt 2005). In essence Burt argues that broker positions that are able to span structural holes provides advantages due to the connection of otherwise separated entities (Burt 1992; Burt 1997; Burt 2003; Burt 2005). Going back to Granovetter and the concept of weak ties (Granovetter 1973) and on network betweenness centrality as a function of being the connection between otherwise disconnected nodes (Freeman 1977; Freeman 1979), Burt (2010) most recently describes the concept of structural holes as "the general idea that there is advantage in having connections to multiple, otherwise disconnected, groups and individuals" (Burt 2010: 23). Against this background, Burt (2005) specifies the advantage of standing in the structure hole position and thus taking a brokerage position in the following ways (Burt 2005): First, the broker has access to a wider diversity of information. Second, the broker is able to possess early access to that information. Third, the broker can have control over information diffusion. As a result, the broker is in the position of non-redundant information and in the crossroad of information flow; he can easily access the information between separate entities. Hence, the broker might have more opportunity to learn or spread this new knowledge. In addition to the advantage of accessing knowledge, the broker is important because he is the only person who can make contact with the different groups; without the broker, the separate groups would always be separate.

Thus, when it comes to knowledge development, broker positions are important because they can provide access to non-redundant information that are important for the generation of new knowledge. Relating these issue to our context, we assume that subsidiaries in a central brokerage position may be better positioned in order to assess the veracity of the information they receive by comparing and getting different information across sources (Burt 1987). Multiple information sources provide multiple channels to discover new knowledge, and to combine prior and new knowledge in novel ways to generate innovation faster (Gilsing et al. 2008; Van de Ven 1986). As a result, subsidiaries with a high brokerage have more chances to access different knowledge and that their unique position may be able to enhance their ability to innovate. Thus, we expect that subsidiaries who increase their brokerage position within the local research network will have faster access to critical and diverse knowledge and should therefore build up their innovative capabilities faster than subsidiaries not in such a position.

Hypothesis 3. The greater the brokerage position of a foreign subsidiary within the local local host country R&D network the greater the patent rate.

Besides brokerage, the most basic argument that can be drawn from Coleman's study is that actors benefit from being in a dense network structure in which actors are tied to multiple actors, who are connected to one another (Owen-Smith and Powell 2004). There are several advantages of being located in a dense network position. A dense network gives not only access to information but also speeds up information transmission. Another benefit can be derived from the development of trust, norms and culture, which govern actions in the network (Obstfeld 2005). Thus, aside from the brokerage position of the subsidiary, we assume that there is yet another structural characteristic of the network: the vertical layers of the network that lead into the *core* (the densest and most cohesive area of the network) and the position of the subsidiary within the networks layers. Cohesive subgroups in a network are subsets of actors among whom there are relatively strong, direct or intense ties (Wasserman and Galaskiewicz 1994: 249). In social network analysis, the notion of sub-group is formalized by the general property of cohesion among subgroup members based on specified properties of the ties among the members. However, since the property of cohesion of a subgroup can be quantified using several different specific network properties, cohesive sub-groups can be formalized by looking at different properties of the ties among subsets of actors. Following recent work in social network analysis we utilize an analysis which groups actors into network strata based on both actor prominence and network cohesion, *a k-core* decomposition which we will explain in the method section in greater detail.

The analysis of k-core values of network nodes leads – in its simplest way - to the distinction between members of a cohesive subgroup versus non-members, e.g. nodes that do not belong to any cohesive subgroup. In a more refined interpretation, the coreness value indicates the distance of firms towards the core of the network, its most dense and most cohesive region. *Coreness* thus indicates membership in a dense, cohesive and robust subgroup of the network. Furthermore, coreness reflects connectivity. A high coreness value is based, in part, upon a high nodal-degree, e.g. the higher the number of ties of the node, the higher its coreness (k-kore value). A firm with a high coreness value will thus reside in a cohesive and robust area of the network. Thus, one can assume that cohesion leads to “increase information sharing among partners, build familiarity and norms” (Baum, Shipilov, & Rowley 2003: 697; Rowley, Greve, Rao, Baum, & Shipilov 2005: 502).

However, in contrast to the advantages positional brokerage of a subsidiary has for its access to important new and diverse knowledge, we assume that being located in the core of the network is not as beneficial for an organization as being located in the periphery of the network. We assume that for true exploration which "includes things captured by such terms as search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation" (March 1994: 237) pressures firms to search for new information. Cohesive ties in the core of the network are of course important because it breeds strong bonds of mutual understanding and trust (Gulati 1995a; Gulati 1995b; Moody and White 2003: 122). However, the same strong bonds may also serve as a filter for information and perspectives reaching the actors, generating a lock-in that isolates them from the access to new information (Uzzi 1997b) which is essential for the generation of new knowledge. There are thus the negative consequences of overembeddedness in the network core,as emphasized by prior research (Uzzi 1997b). Even more so, as Fleming notes, being a member of a "small world" does not improve the regional innovation output (Fleming, King III, & Juda 2007). Thus, while the coreness reflects the ease of accessing the information and resource rich core of the network, we expect that that exploration needs more than access to information and resources and trust and stability. It needs the inflow of new information and new knowledge never heard of or seen before. Finding this in the core is less likely than in the periphery of the network.

Turning to our setting, we assume that the core of the local network reflects the area of the network with the highest degree of resources and knowledge the subsidiary can tap into. However, for the inflow of new information the cohesiveness of a the network core is a disadvantages. Being located in the core assumes that an organizations has less nonredundant relations which are important to increase innovation output. Thus, the faster the subsidiary will move into the core of the network, the lesser it will benefit from the different knowledge available in the network peripheries. This leads us to our fourth hypotheses:

> *Hypothesis 4. The higher the coreness of a foreign subsidiary within the local host country R&D network the lower the patent rate.*

5. Method

5.1 Data Sources and structure

The longitudinal datasets used in the study are German subsidiaries of pharmaceutical MNCs active in the field of biotechnological lifescience and located in the "Biotechnologie-Cluster Rhein-Neckar"-region in Germany. We observed this regional network from the year 1996 until the end of 2009. We test our hypotheses on a longitudinal data set comprising the collaboration and patenting activities of the pharmaceutical subsidiaries of the MNCs located in this region and active in the field of biotechnology. Our sample is based on secondary data, webpage data, and the yearbook data that is published yearly by the German association for biotech firms "BIOCOM AG". The BIOCOM AG was founded more than 20 years ago and is the most important information and communication platform for biotechnology and life sciences in Europe.

In particular we used the following primary sources to collect our data. The first were the "Yearbooks of the German Biotechnology Industry", a collection based on a survey of all organizations in the field of biotechnology as well as related field. The yearbook is published yearly by the German firm BIOCOM AG. The addresses from this source were used to identify the number of dedicated biotech firms, the pharmaceutical and chemical firms, the geographic location of the organizations, information on alliances, information concerning the organizational types and some further more general information (BIOCOM AG 2009). The second source was the daily registration and deregistration records of the German Commercial Register in Berlin. The third source was archival data coded from the monthly TRANSCRIPT newsmagazine that reports on the German biotech industry, where we search for information about alliance. We consulted the yearbook data (2009) provided by the BioRN Cluster Management GmbH for further information about the genesis and evolution of the cluster, the main players in the cluster, and the resources and capabilities of the cluster (BioRN Cluster Management GmbH 2009). We also looked on the web pages of the different organizations that we identified via the BIOCOM yearbook to gather further information about their main business areas, their performance and histories. We also looked on the webpages of the subsidiaries to search for information about alliances. The focus of our research attention are the subsidiaries of pharmaceutical MNCs active in the lifescience field of biotechnology in the "Biotechnologie-Cluster Rhein-Neckar"-*region*. Therefore, other organizations in the organizational field, such as biotech firms, universities, government laboratories, et cetera enter our data only as strategic alliance partners of the pharma subsidiaries. We used our data to construct an event history for each organization that include information on the number, timing and sequence of the events (e.g. strategic alliances of varying kinds) that are being examined. We used this information to construct a series of yearly network variables.

5.1.1 The "Biotechnologie-Cluster Rhein-Neckar"

The "Biotechnologie-Cluster Rhein-Neckar" is located in the south-west of Germany. At present, several large pharmaceutical and biochemical firms, four large research institutes and universities that are active in the field of biotechnology and 27 dedicated biotech firms, belong to the "Biotechnologie-Cluster Rhein-Neckar". With Febit holding GmbH, SYGNIS Pharma AG (formerly LION Bioscience AG) and mtm laboratories AG some of the largest German biotechnology firms are located in this cluster (BIOCOM AG 2009; BioRN Cluster Management GmbH 2009). The region has a long history in the context of biotechnology. For example, Boehringer Mannheim has already started in the year 1977 with first attempts in genetic engineering, in the year 1986 with the production of recombinant enzyme and launched its first drug ("NeoRecormon") based on genetic engineering in the year 1990. Another key feature of the cluster is the early formation of dedicated biotech firms. Already in the year 1982 "Orpegen Pharma", a major amino acid producer, was founded in the "Biotechnologie-Cluster Rhein-Neckar". In the year 1983, Genbiotec (now BIOMEVA GmbH) a major producer of recombinant proteins was founded. Three years later, another large and successful biotech firm called Biopharm was founded in the cluster (Heidelberg).

To define whether or not an organization belongs to the Rhine-Neckar cluster, we had to set regional boundaries. In general, the German postal system uses a 5 digit system, the first digit reflecting the city, the second digit the suburbs within the city, and the last 3 digits the street level. Clustering at the 2-digit level represented a compromise between a smaller geographic region such as the street level, and a larger region such as the city district or the state ("Bundesland"). In doing so, we allocated a firm's presence in the cluster according to the 2-digits postal code while the organization's allocation within the cluster is narrower (according to the 5-digits postal code). The location information to construct the cluster was taken from the postal addresses published yearly in the BIOCOM AG Yearbooks. Following this process, the "Biotechnologie-Cluster Rhein-Neckar"-cluster has been set to the 2-digits postal codes 67, 68 and 69. Our measure therefore reflects a significant smaller area then the Metropolitan Statistical Area (MSA), that is commonly used in U.S. based cluster studies (Audretsch and Stephan 1996; Audretsch and Stephan 1999; DeCarolis et al. 1999; Krugman 1991; Shan and Song 1997; Zucker, Darby, & Brewer 1998). In further studying the *region* we identified the 2-digit postal codes that are directly adjacent the cluster as the boundary of the region. Following this process, the "Biotechnologie-Cluster Rhein-Neckar"-*region* can be characterized by the following 2-digits postal codes: *55, 64, 66, 67, 68* and *69*.

5.1.2 Dependent variable

We measured our dependent variable as the number of patent applications for subsidiary i, in year t. For the period under observation (1996-2009) we found 1,828 patent applications of

German pharmaceutical subsidiaries that were filed within the biotechnological technological (IPC) classification. We coded for the patenting application frequency of each subsidiary located in the “Biotechnologie-Cluster Rhein-Neckar”-*region* from the year 1996 until 2009. The patent applications are accurate to the day, e.g. a patent may be applied for on June 15th 1999. However, we counted these events within yearly intervals (Ahuja 2000: 437). Following prior research, we assign a patent to a biotech firm at the date of application rather than the date of granting because in general, the application date is a more accurate representation of the date of innovation (Ahuja 2000: 437). We used the European Patent organization (EPO) as the primary source for the assignment of patents and the assignment date. Thus, we obtain patent counts for each year and each subsidiary in the region.

In using patent data we follow the research efforts of several other scholars who have used patents as a measure of innovative success of firms (Ahuja 2000; Engelsman and Van Raan 1994; Gilsing et al. 2008; Henderson et al. 1994; Jaffe, Trajtenberg, & Henderson 1993; Rosenkopf et al. 2001; Zaheer and Soda 2009). We have to acknowledge that there are a number of potential limitations to using patent data to study innovation. First, patents are a partial measure of the production of organization knowledge: they may capture codified knowledge flows but not tacit knowledge (such as that embedded in organizational routines). Our study therefore captures innovation and knowledge exchanges of articulated technological knowledge. However, empirical findings suggest that codified knowledge flows (represented by patents) and tacit knowledge flows are closely linked and complementary (Mowery, Oxley, & Silverman 1996).

Another potential drawback in the use of patent data is that patenting is itself a strategic choice and, hence, all technological innovations may not be patented and the pure count of patents does not tells us anything about the impact or the scope of an innovation. Nevertheless it is a common used measure of innovation output (Ahuja 2000; Gassmann, Reepmeyer, & Von Zedtwitz 2008: 133f). However, like for example the chemical industry and the pharmaceutical industry, the lifescience industry can be characterized through a high level of collaboration while, at the same time, patents can be described as a "meaningful measures of innovation" in these industries (Ahuja 2000: 433). In particular, the nature of competition in the field of liefescience encourages fast patenting of innovations. Patents form the intellectual capital of this industry (Ernst & Young 2003; Shan et al. 1997). As Ahuja (2000) describes: "[t]he link between patents and innovation is likely to be stronger in industries in which patents provide firms with fairly strong protection for their proprietary knowledge" (Ahuja 2000: 433). "Due to the significant R&D spending in the pharmaceutical industry and the high risks associated with new drug development, patent protection and the subsequent management of intellectual properties particularly important in this industry" (Gassmann et al. 2008: 133f). In this context, the race to patent innovations becomes a crucial aspect of competitive strategy: given that patents are granted to the first to invent the idea, running second provides little benefit.

5.1.3 Independent variable

Our independent variables are size (density) and the diversity of the regional network (Herfindahl), network brokerage (betweenness centrality) and the k-core value of the subsidiaries. All these variables are updated annually.

To measure the density of the regional network we calculated the total number of ties divided by the total number of possible ties. The UCINET program was used to construct the density of the regional network per year. To account for the marginally declining influence of the density we squared the density variable to construct a non linear course.

To measure the diversity of the regional network we constructed the Herfindahl index according to the formula:

$$H = \sum_{i=1}^{n} (s_i^2)$$

where s_i is the density of organization *i* in the cluster, and *n* is the number of different organizations. The density s_i was calculated as the number of organizational type (biotechnology firms, pharma-subsidaries, research instutes and univerities and others) in the region divided by the total number of organizations in the cluster. The density measures were then squared and summed to calculate our diversity measure. Thus the index describes the entropy of organizational types in the region, considering the size of the region.

To measure brokerage of the subsidiaries we applied the concept of betweenness centrality that was introduce by Freeman (Freeman 1977; Freeman 1979). Betweenness centrality "measures the extent to which a particular point lies 'between' the various other points in the graph" (Freeman 1977; Freeman 1979; Scott 2000: 86). The betweenness of a point Y for a specific pair of points X and Z is defined as the "proportion of geodesics connecting that pair which passes through Y – it measures the extent to which Y is 'between' X and Z" (Scott 2000: 87). As a proportion the value can vary from zero to one. Thus, a value of 1 means that a pair of points are completely dependent on one particular Y for their connections" (Scott 2000: 185). Brokerage is some sense can be related to the concept of betweenness centrality. Betweenness centrality is "a measure of the influence a focal firm has over the information through the alliance network. In other words, it also forms a network wide (global) measure and takes direct and indirect ties into account. This is important as this indicates how far a firm can reach potentially all (including distant) parts of the network. This provides us with an indication of the potential for novel combinations that a firm may have" (Gilsing et al. 2008: 1724). The UCINET program was used to construct the yearly betweenness centrality score for each subsidiary in the regional network.

Our measure of cohesive subgroups based upon nodal degree will be the k-core of the node under observation. The k-core measure indicates the cohesiveness of the subgroups (i.e. components) in the net, based upon the degree centrality of the nodes in the subgroup. A k-core is a subgroup in which each node is adjacent to at least a minimum number k, of the other nodes in the subgroup (Wasserman et al. 1994: 266). Since this measure is quantified by the degree of the node in a graph, this subgroup method focuses on nodal degree. Subgroups based on nodal degree require nodes to be adjacent to relatively numerous other subgroup members. However, unlike a clique definition that requires all members of a cohesive subgroup to be adjacent to all other subgroup members, this alternative requires that all subgroup members be adjacent to some minimum number of other subgroup members (Wasserman et al. 1994: 263). As discussed previously, the k-core measure indicates the cohesiveness of the subgroups (i.e. components) in the net, based upon the degree centrality of the nodes in the subgroup. Thus, the larger the k-value of a node, the larger the cohesiveness of the subgroup in which it is embedded. Given our observation that the most cohesive area of the two networks represent the respective network-core, a high k-value of a subsidiary reflects its coreness in the net. The UCINET program was used to construct the k-core strata for each subsidiary and each organization it has ties with per year in the regional network.

5.1.4 Control variables

We included as controls the age of the subsidiary and the duration of the subsidiary in the regional network. We also controlled for the location of the headquarter. We expect that these variables affect the likelihood of patenting. To measure the age of the subsidiary we simply counted the years since the foundation of the subsidiary in the region. To measure the duration in the regional network we had to define a starting time for the existence of the regional network. The founding of the region was defined to correspond with the time of the founding of the biotech industry in Germany in the year 1996. This allowed us to calculate the duration of the firm in the regional network by subtracting the starting time of the cluster from the time of the event (in years). We therefore measured the duration of a firm in the cluster whenever an event under observation occurs. Finally we integrated a dummy variable for the location of the headquarter to account for the liability of foreignness (Eden and Miller 2004; Nachum 2009; Zaheer and Mosakowski 1997).

5.2 Model

Since the occurrence of patents over time for a firm represents a series of repeated events within a specific time span that takes only non-negative values, a count model analysis is a useful analytic technique. Thus, we used the Poisson regression count model approach to analyse our data (Ahuja 2000: 436; Hausman, Hall, & Griliches 1984). The Poisson distribution captures the likelihood that an event (here patent applications) occurs within a specific time period. The Poisson distribution is defined as:

$$\Pr(Y_t = y_t) = \frac{\exp(-\lambda_t)\lambda_t^{y_t}}{y_t!} \qquad y_t = 0,1,2...$$

While $\Pr(Y_t = y_t)$ is defined as the likelihood that the actual number of events in a specific time period t equals a fixed number y_t of events. λ_t is the mean number of events and equals the rate of events. Yet, considering the problem of overdispersion a variation of the poisson model, a negative binomial regression model is more appropriate (Beck 2005: 430). The negative binominal records the number of occurrences (counts) of an event when the event has an extra-poisson variation, With the help of a negative binomial regression models and the inclusion of a gamma-dispersed error term we can control for overdispersion. However, the ordinary negative binomial regression will have difficulties with zero-truncated data because the model tries to predict zero counts even though there are no zero values in our data because we included only (positive) patent events. In such a case a zero-truncated negative binominal regression model might be preferred over an ordinary negative binominal regression model (Mittelhammer, Judge, & Miller 2000: 157ff).

In order to test if our data is overdispersed we calculated the log of the over dispersion parameter “alpha”. If alpha equals zero then there is no over dispersion. With the likelihood ratio chi-square test we predicted the term alpha. If the test is significant, as it is in our case, then the zero-truncated negative binomial model is preferred over the zero-truncated poisson regression model. Thus, we used a zero-truncated negative binominal model to analyze our data. We also calculated the pseudo-R^2 value. The pseudo-R^2 for our full zero-truncated negative binominal regression model is statistically significant.

All our parameters were estimated using the STATA 11 SE program. We used four models to evaluate our hypotheses. The first model included only control variables and constitutes a baseline model. The second model included the control variables and the structural regional network variables. The third model includes all variables. This model was used to evaluate the hypotheses. Because patents are likely to correspond to activity preceding the application, we also run a fourth model including one-year lead variables with respect to our structural and positional regional network variables (Ahuja 2000: 437). We thus allowed a time difference in the occurrence of patents due to the duration of the patenting process itself.

6. RESULTS

We are still in the process of further refining our study, so at present we present the preliminary results of our first runs. However, a close examination of the models unveils some impressions that are consistent. We will discusses these findings below.

6.1 Descriptive results

Due to complementary assets held by each type of organizations, interorganizational relationships such as R&D cooperation's, are frequent in the lifescience industry (Gambardella 2010: 147f). In fact, the biotechnology and lifescience industries have been identified as the industries with the highest alliance frequency among several industries characterized by high alliance activity (Hagedoorn 2002). Over the last years, the dyadic ties are integrated into regional networks, that form the objects of our analysis. Figure 2 provides an overview of the development of the total number of R&D-ties and nodes in the "Biotechnologie-Cluster Rhein-Neckar". The number of nodes has increased until the year 2004 and has decreased in the year 2005. Since the year 2006 the number increased continuously. A similar pattern can be seen for the development of the number of ties.

-Figure 1 About Here-

To get a first overview of the evolution of the regional network structure and the position of the organizations located in the "Biotechnologie-Cluster Rhein-Neckar" network, we visualized the development in two year steps for a synopsis (Figure 2). To distinguish the different locations of the alliance partners we used colors. We used the color black for organizations in the region, dark grey for national partners and light grey for international ones. To distinguish different organizational types we used different shapes (Pharma subsidiaries:

rounded square; biotech firms: circle; research institutes/universities: diamond;; supplier: up-triangle; service: square, government: downtriangle, network: thing (this shape is a combined uptriangle and downtriangle); finance: box, other: plus); centrality in our maps is represented through the size of the nodes.

-Figure 2 About Here-

What can we interfere from this visualization? As the graphs indicate, the pharmaceutical subsidiaries play a prominent role in the regional network. In the beginning, in the year 1996, the regional network comprises three locally rooted organizations, one research organization and two pharmaceutical firms. In the year 1996 the regional network comprises two components. Already in the year 1996 one research institute collaborated with one pharmaceutical subsidiary. The subsidiary has the highest centrality value in the year 1996. In the year 1998 new members entered the network. The regional network now comprises 6 unconnected components and the most central organization is a biotech firm. It is interesting to note that already in the year 1998 some organizations established R&D alliances with international firms. For example, one pharmaceutical MNCs started an alliance with two US-biotech firms. In the year 2000 the regional network comprised 8 unconnected components. In the year 2002 the regional network already comprised 12 unconnected components. The most central organization is still a biotech firm and this firm will have this position until the year 2008. Yet, the network evolves. In the year 2004 the regional network comprised 19 unconnected components. Two years later the regional network comprised 26 unconnected components and reached the maximum. In the year 2008 the regional network comprises 18 unconnected components. Thus, recently, the number of components decreases which reflects an increasing connectivity in the regional network.

6.2 Multivariate results

Figure 3 illustrates our dependent variable: the number of patent applications from the pharmaceutical subsidiaries in the regional network “Biotechnologie-Cluster Rhein-Neckar” over time. While only a few patents applications occurred in the early years (1996-1999), the number of patent applications reached its maximum with 388 applications in the year 2001. Since the year 2005 the number decreased from 203 to 107 in the year 2009.

-Figure 3 About Here-

We will now turn to our hypotheses linking network embeddedness to the innovative speed of the subsidiaries. Table 1 and Table 2 provides means and standard deviations for the variables in our models as well as a correlation matrix.

-Table 1 About Here-

-Table 2 About Here-

Table 3 provides the results of our zero-truncated negative binominal regression model. Model 1 provides parameter estimates for only the control variables. Model 2 adds parameter estimates for the structural regional network variables. Model 3 is the full model. We interpret our variables based on this model. Model 4 includes prior variables for the positional and structural regional network variables. As Model 4 in Table 3 shows, the effects of the main variables does not change significantly if we run the model controlling for time priority.

-Table 3 About Here-

Our first Hypothesis predicted that the size (density) of the local host country R&D network, will have a positive, yet marginally declining effect on the foreign subsidiaries patent rate. We find support for this Hypothesis (Model 3 in Table 3). However, the network density is only one factor. While looking at the diversity of the regional network in greater detail (Model 3 in Table 3) we find, oppose to predicted, that the diversity, reflected by the number of different organizations such as biotech firms, universities and research institutes, has a non-significant influence on the innovation output. Our third Hypothesis stated that the greater the brokerage of a foreign subsidiary within the local host country R&D network the greater the patent rate. We find significant support for this Hypothesis (Model 3 in Table 3). A high level of brokerage of a foreign subsidiary within the local host country R&D network has a significant positive influence on the innovation output. Finally, in Hypothesis 4 we assumed that the lesser the coreness of a foreign subsidiary within the local host country R&D network the greater the patent rate. We also find significant support for this Hypothesis (Model 3 in Table 3). The coreness of foreign subsidiary within the local host country R&D network has a significant negative influence on the innovation output.

As the establishment of regional network ties need time to be built up and kept alive we expect subsidiaries who have entered the regional network early in time to benefit from the described advantages faster. Thus, we controlled for this factor. We found that the age of the subsidiary has a non-significant influence on the innovation output (Model 3 in Table 3). However, with regard to the duration in the regional network we found that this has a significant negative influence on the innovation output. Finally, the location of the headquarter of the MNC in Germany has a significant positive effect on the innovation output (Model 3 in Table 3). We will discuss our findings in the next section.

7. DISCUSSION AND CONCLUSION

Due to the fact that high-value knowledge is increasingly spread all over the globe, the competitiveness of MNCs is to a growing extend dependent on the ability to establish a presence at multiple locations to access innovation networks of new knowledge and capabilities (Kuemmerle 1997). Our study highlights the importance of brokerage as well as location in the regional network on MNEs‘ subsidiaries innovation performance. A high level of brokerage leads to better access to a broad scope of new and diverse knowledge which is important for the innovation capability of the subsidiary. The contribution of brokerage on innovation output is related to informational diversity insofar as such diversity refers to the differences in knowledge bases and perspectives a subsidiary can access. This allows subsidiaries in such a position to accumulate heterogeneous knowledge more quickly which, in turn, will lead to a higher innovation output (Dekkar, Stokman, & Franses 2000).

Besides brokerage, we found that the location of the subsidiary in the regional network also has a strong influence on the innovation output. The core of the network is supposed to be the most dense region of the net (Seidman 1983: 276). Yet, subsidiaries who are situated the core may find it difficult to recharge "the freshness of their ideas and escape the pressures to conform to the established norms of the field" (Cattani, Colucci, & Ferriani 2010: 11). The upshot of a peripheral position is the "exposure to fresh stimuli and original sources of inspiration or stimuli that may facilitate divergent thinking" (Cattani et al. 2010: 11). This, in turn, seems to lead to a higher innovation output.

While our research highlights some important findings about the role of regional networks and brokerage in particular, we are only at the beginning of our research. We are planning to expand our research in several ways. Empirically, we are interested in expanding our research setting and taking different regions and multiple MNCs subsidiaries into account. In line with more recent literature on clusters that views clusters as venues of enhanced knowledge creation (Arikan 2009; Bell et al. 2009), a cluster's knowledge creation capability and the openness of the cluster, e.g. the number of international alliances the firms in the cluster have, might have an influence on the role and the importance of brokerage as well as on the core-periphery position. In fact, there might be an important tension between the two positional variables that might be moderated by the structural characteristics of the regional network. Thus, future research can be developed taking not only different regions (different structural characteristics and attributes in regards to different organizational types) and multiple subsidiaries into consideration, but also the role the subsidiary plays within the MNE and their evolution over time.

There might also be different strategies, which explain a more favorable MNC strategy of developing the global competence creating the role of subsidiaries. The idea that multinational subsidiaries are heterogeneous according to their technological capabilities and roles can be traced back to Ghoshal and Bartlett's study (1991) on subsidiary roles (Bartlett et al. 1990; Ghoshal and Bartlett 1991). These authors argue that the tasks of affiliates can be classified in three categories: creation, adoption and diffusion. While creation refers to use subsidiary's own technical and managerial resources to respond to local circumstances; adoption is conceptualized to adopt innovation developed by parent firm or a central R&D facility, or other national subsidiaries of the firm. Finally, diffusion is a means to diffuse local innovations back to the parent firm or to other subsidiaries.

Conceptually, our research also reemphasizes the value of localized subsidiary innovation. Localized subsidiary innovation is "the extent to which subsidiary learns from its local environment" (Mu, Gnyawali, & Hatfield 2007: 82). This concept is especially important to challenge the traditional notion that states that knowledge is mainly created and generated at the headquarter (Doz, Santos, & Wiliamson 2001). When subsidiaries engage in localized innovation, they can establish the standing within the corporate MNC network as a valuable source of knowledge. In this framework, subsidiaries' local embeddedness first lead to localized subsidiary innovation, which then leads to greater knowledge outflows to the headquarter. When subsidiaries engage in greater innovation sourced from the host country, they can combine the innovation with knowledge existing within the subsidiaries to create valuable knowledge stock (Almeida et al. 2004; Mu et al. 2007). Existing knowledge stock within the subsidiary combined with externally acquired information and experiences improves the knowledge stock’s uniqueness, novelty and heterogeneity. Locally acquired innovation combined with subsidiaries’ existing knowledge stock are more likely going to be perceived as highly valuable by headquarter and peer subsidiaries, and they are more likely to be receptive of the knowledge, and subsequently facilitates greater knowledge outflows to the headquarter or other subsidiaries in the MNC´s network. Yet, a subsidiary can be increasingly embedded in both MNC network and local network (which themselves will become highly interactive), impacting its MNC and local absorptive capacity, and therefore enhance its realized innovation

FIGURE 1: Number of ties and nodes in the region of the "Biotechnologie-Cluster Rhein-Neckar"

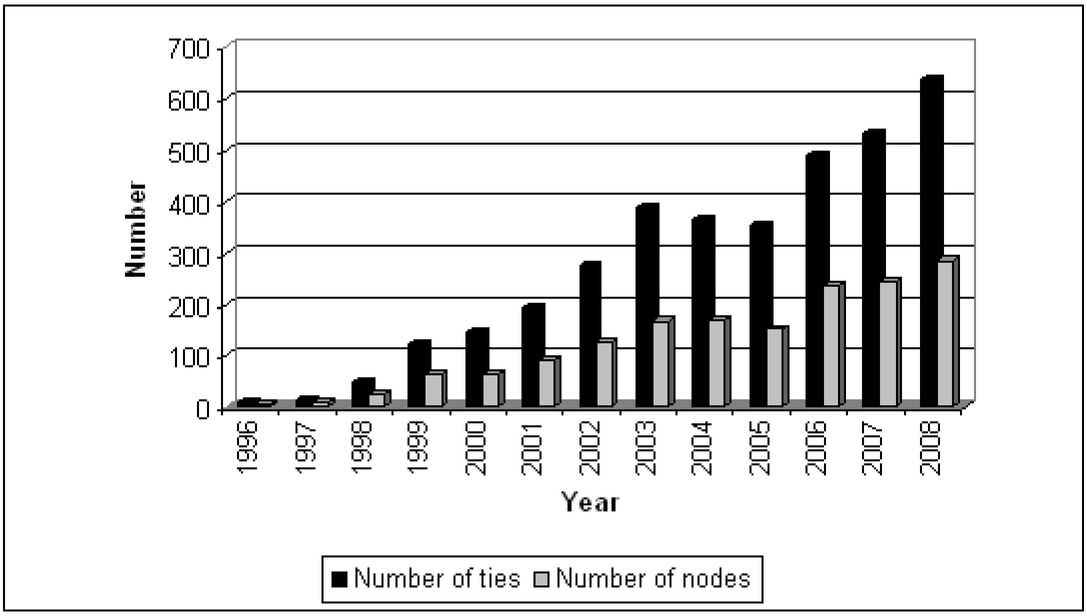

FIGURE 2: Number of patent applications from pharmaceutical subsidaries in the regional network of the "Biotechnologie-Cluster Rhein-Neckar"

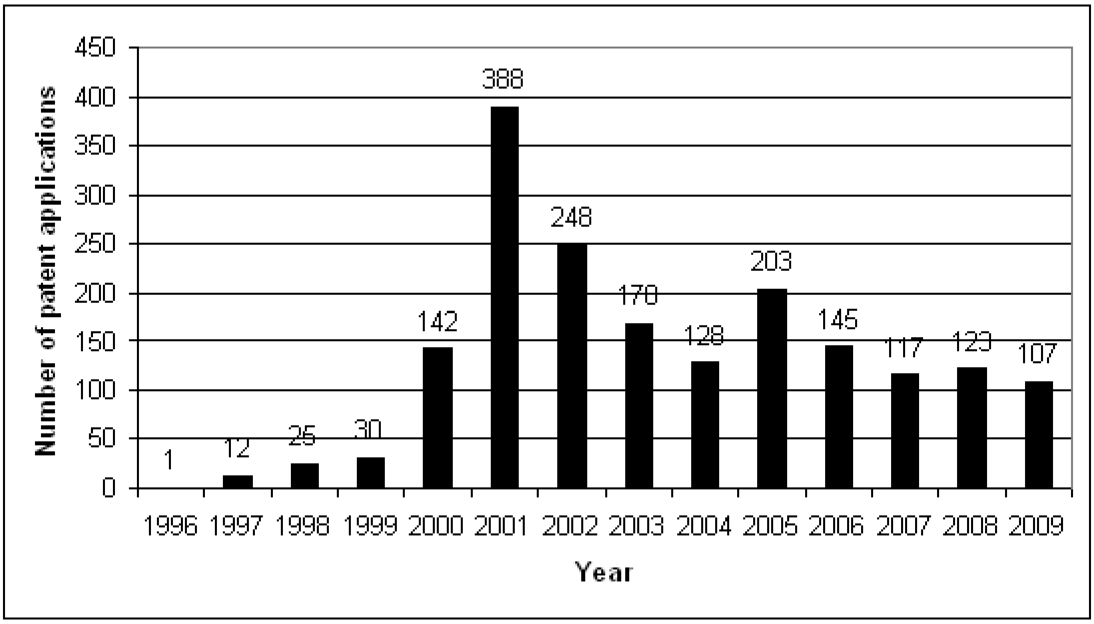

FIGURE 3: Maps of the “Biotechnologie-Cluster Rhein-Neckar”-region network (pharma subsidiaries: rounded squares)

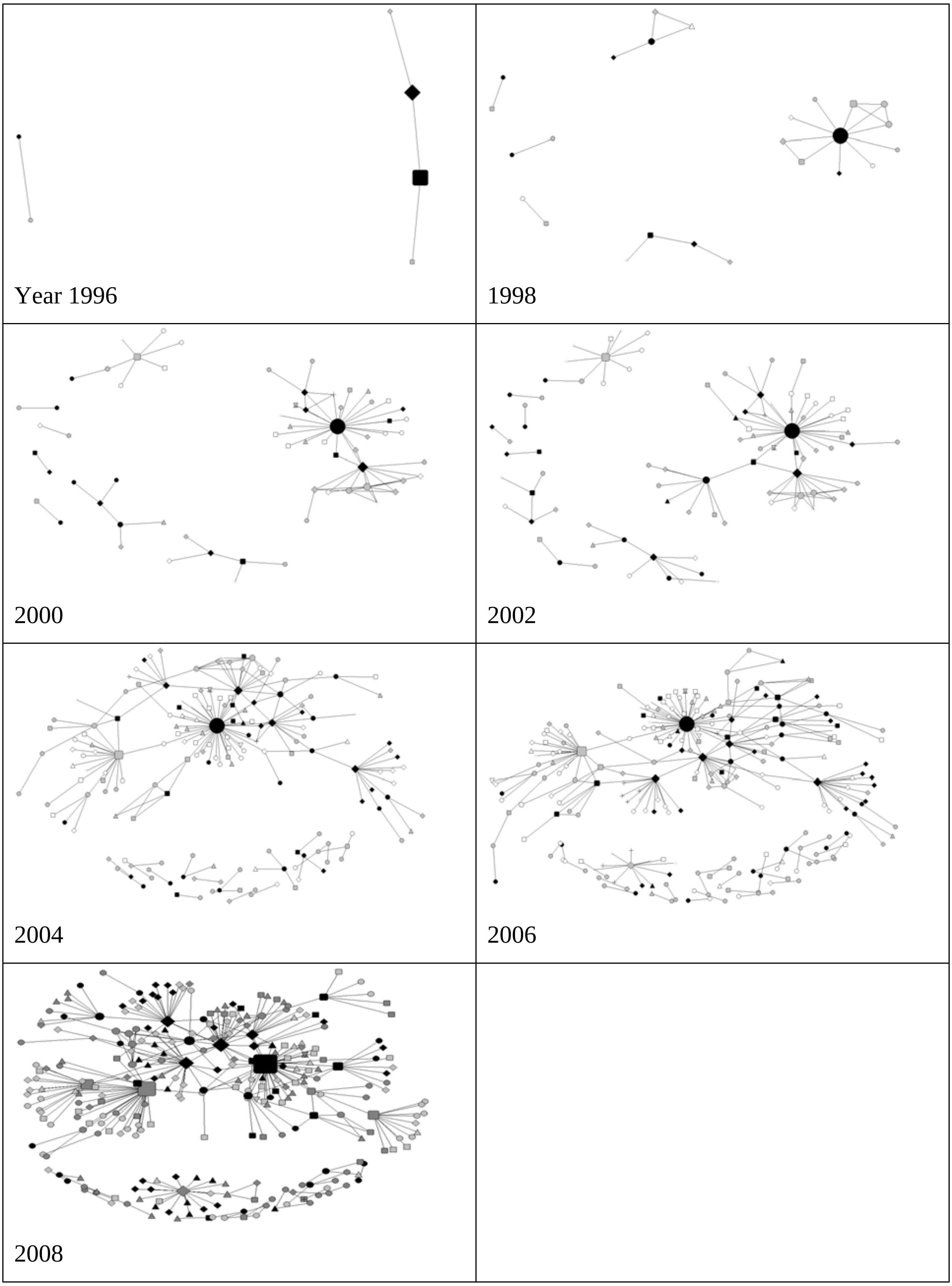

TABLE 1: Descriptive statistics on Pharma MNC´s subsidiaries

	Mean	Std. Error	[95% Conf. Interval]	
Age Sub	3.675088	.0911157	3.496378	3.853799
Duration RN	3.437133	.09318	3.254373	3.619892
Location Headquarter	.8572268	.0084824	.8405897	.8738638
Size (Density)	6.466922	.064851	6.339732	6.594112
Diversity RN(Herfindahl)	5.773796	.0593504	5.657388	5.890203
Betweenness centrality	10.41389	.1833365	10.05432	10.77346
K-value	1.89953	.0072891	1.885233	1.913827

TABLE 2: Correlation matrix

	Age Sub	Duration RN	Location Headquarter	Size (Density)	Diversity (Herfindahl)	Betweenness centrality	K-value
Age Sub	1.0000						
Duration RN	0.9380	1.0000					
Location Headquarter	-0.2275	-0.0707	1.0000				
Size (Density)	-0.3394	-0.3113	0.1556	1.0000			
Diversity (Herfindahl)	-0.4243	-0.4389	-0.0020	-0.3793	1.0000		
Betweenness centrality	0.1802	0.1823	0.1153	0.0441	-0.3298	1.0000	
K-value	-0.0320	0.1051	0.6066	0.0997	-0.1131	0.5082	1.0000

TABLE 3: Zero-truncated negative binominal regression model of the patent rate of pharma subsidiaires

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Age Sub	-.02189 (.01326)	.01161 (.01346)	.00069 (.0164)	-.00659 (.01421)
Duration RN	-.05117*** (.01274)	-.02686* (.01221)	-.04002** (.0155)	-.02508 (.01311)
Location Head-quarter	.20119*** (.05218)	.19033*** (.05007)	.47431*** (.0735)	.18188*** (.05336)
Size (Density)		.5983*** (.04271)	.35303*** (.04392)	
Size Squard (Density)		-.04288*** (.00302)	-.02484*** (.0031)	
Size (Density) (prior)				.41899*** (.04185)
Size Squard (Density) (prior)				-.02892*** (.00298)
Diversity RN (Herfindahl)		-.05827*** (.00862)	-.01137 (.00904)	
Diversity RN (Herfindahl) (prior)				-.00969 (.00895)
Betweenness centrality			.02349*** (.00286)	
Betweenness centrality (prior)				.01955*** (.00276)
K-value			-.5305*** (.08813)	
K-value (prior)				-.21094** (.06755)
Constant	4.6872*** (.05204)	3.0571*** (.18221)	4.0649 *** (.24425)	3.5102*** (.22393)
Lnalpha Con-stant	-.34874*** (.03269)	-.47988*** (.03276)	-.61162*** (.03386)	-.64278*** (.03379)
Statistics				
Chi2 (Df)	186.09 (3)	442.02 (6)	447.5 (8)	426.77 (8)
N	1828	1828	1702	1692

Legend: legend: coefficient/(standard error); * p<.05; ** p<.01; *** p<.001

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