

Chapter 6

Strategic and Innovation Networks in the Flanders Biotechnology Industry

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Abstract For organizations in high-technology industries, knowledge is a critical resource that can be accessed through inter-organizational networks. However, for industries characterized by a heterogeneous set of actors, little is known about how different networks within the industry interact. Therefore, our research question is: How similar are the strategic network and the innovation network in the biotechnology industry? To answer our research question, we study two networks of interest. First, the Board-of-Directors-network serves as a proxy for the strategic network that fosters knowledge transfer between organizations. Second, we analyze the innovation network by using the patent network that emerged from collaborative innovation activities. Subject of analysis is the Flanders biotechnology industry, which is characterized by strong performing research institutions, large firms and innovative SMEs. We use social network analysis methods to measure the similarity of both networks and to identify their key actors. We find that a connection between two organizations in the strategic network increases the probability of forming a new connection between the same organizations in the innovation network, or vice versa. This shows that collaborations between two organizations on one network level can lead to an interlocking of the organizations at other network levels. Our results also suggest that few companies establish and maintain a strong position in the biotechnology innovation network. This network is dominated by academic institutions, which are the key producers of scientific

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knowledge. Interestingly, the BoD-network has a more balanced composition and power structure and knowledge on strategic issues is transferred across a wide range of industrial actors. We also highlight the strong position of spin-off companies in the BoD-network and the absence of large firms in both networks. Our findings call for more research on the causal mechanisms of network formation and on the relationship between multiple networks within one industry.

6.1 Introduction

Innovation and organizational learning are critical in today's competitive global environment. Therefore, accessing and integrating external knowledge is crucial for an organization's success, especially in a knowledge-intensive industry such as the biotechnology industry (Cohen and Levinthal 1990; Grant 1996; Grant and Baden-Fuller 2004; De Clerq and Dimov 2008). Firms can access these external resources, such as knowledge, through inter-organizational networks (Gulati 1999). Networks are formed by the links between firms and other organizations and/or stakeholders. These links can, for example, emerge through a range of processes such as the formation of strategic alliances, the execution of collaborative research projects or through informal contacts. In general, a positive relation between the strength of a firm's network (position) and the firm's performance, also in terms of innovativeness, is witnessed (Baum et al. 2004; Zaheer et al. 2010). Network research is complementary to the theory on the resource-based view on the firm, which predominantly focuses on internal firm characteristics to explain firm performance (Wernerfelt 1984; Barney 1991; Newbert 2007). As a result, variances in organizational performance are best explained by a combination of both the organization's internal capabilities and its network characteristics (Zaheer and Bell 2005; Zaheer et al. 2010).

We investigate and compare both the strategic network and the innovation network of regional biotechnology organizations. For this purpose, we use two types of networks: the Board-of-Directors (BoD)- and the patent network. The BoD-network is the network that emerges when two or more organizations share at least one director (Dooley 1969). This strategic network plays a key role in transferring knowledge and fostering inter-organizational learning and innovation, especially on management practices and governance (Davis and Mizruchi 1999; Lyson and Raymer 2000; Kogut and Walker 2001; Davis et al. 2003). Patent networks, on the other hand, emerge when two or more organizations jointly apply for a patent. Patents are the result of an organization's innovative activities (Fabrizio 2009); so shared patents are the result of scientific or technological collaboration between the organizations involved. Hence, patent networks uncover the scientific and technological knowledge flows among organizations (Li et al. 2007).

We identify two research gaps with regard to inter-organizational networks and innovation. First, previous research mainly focused on a homogeneous group of

organizations such as financial institutions or Fortune 500 companies (e.g. Davis et al. 2003; Conyon and Muldoon 2008). However, when studying knowledge transfer in the biotechnology industry, we need to assume that knowledge is produced and shared by a heterogeneous set of organizations such as universities, academic spin-offs and industrial conglomerates (Swann and Prevezer 1996; Coenen et al. 2004). Second, even when a heterogeneous set of actors has been studied, analyses are mainly limited to one particular network (e.g. Balconi et al. 2004 study the Italian inventor network and distinguish between academic and non-academic inventors). Nevertheless, analyzing multiple networks for the same industry may help develop a more thorough insight in the network dynamics of knowledge transfer (Zaheer et al. 2010). In this chapter we investigate and compare the two networks of interest for a heterogeneous population in order to answer our research question: How similar are the strategic network and the innovation network in the biotechnology industry?

This chapter is built up as follows. First, we discuss the relevant literature and clarify our research objective before describing the data. Next, we discuss the methodology and results of our research. The final section reports on the main conclusions and limitations of the study.

6.2 Literature Review

Strong inter-organizational networks—sometimes referred to as ‘small worlds’—lead to a higher level of firm innovativeness (Baum et al. 2004), regional success (Saxenian 1994) and effective knowledge transfer (Almeida and Kogut 1999; Singh 2005). Main reasons for this effect are that strong inter-organizational networks allow for (1) more effective knowledge transfer among the networked organizations; (2) the existence of knowledge spill-overs within the network; and (3) the sharing of resources (Ahuja 2000; Schilling and Phelps 2007). In the biotechnology industry in particular, the number of collaborative relationships a biotechnology firm is engaged in is found to have a positive influence on its innovative output (Shan et al. 1994). As a result, the locus of innovation is found within networks of learning, rather than within firms (Powell et al. 1996), which explains the increased interest in analysing the role of inter-organizational networks within industries as a vehicle for knowledge transfer and innovation (e.g. Coenen et al. 2004; Whittington et al. 2009).

With regard to strategic collaboration and knowledge transfer, the BoD-network is one of the main inter-organizational networks of interest. This network is formed by directors that are a member of two or more boards. Hence, the organizations are connected through one or more shared (or ‘interlocked’) directors. The BoD-network emerges because organizations often have to draw from a limited group of potential director candidates already known to the organization. By inviting

professional contacts from similar or known organizations, an interlinking of organizations is formed (Dooley 1969; Davis and Mizuchi 1999). This BoD-network is a formalized structure of strong ties that are based on intense and recurrent contacts (Davis et al. 2003; Robins and Alexander 2004), which are conditions for sustainable and specialized knowledge transfer (Giuliani and Bell 2005; Davis et al. 2003; Non and Franses 2007). The interlocking directors form the connections between boards, which is crucial for information exchange, diffusion of management and governance practices, and for the initiation and decision making on collaborative projects (Davis and Greve 1997; Davis et al. 2003; Cohen et al. 2008). BoD-networks are furthermore crucial for strategic knowledge transfer between organizations (Davis et al. 2003), while sharing a director among multiple organizations may result in inter-organizational alliances (Gulati and Westphal 1999). It is however argued that being highly embedded in this network may also have a negative impact on organizations. Interlocks may decrease firm performance due to capacity constraints of directors and the emergence of group thinking, which may lower the acceptance of novel ideas and hamper negative feedback loops (Boschma 2005). Furthermore, there is a constant risk of sharing sensitive information potentially nullifying a firm's competitive advantage. It is therefore key for an organization to balance the need for external knowledge against the aforementioned drawbacks of interlocked directors (Non and Franses 2007).

The patent network, as a second network type, is the inter-organizational network that emerges when organizations jointly apply for a patent, which is the result of joint scientific and technological efforts and investments (Balconi et al. 2004). Organizations applying for a joint patent have exchanged scientific and technological knowledge. As a result, these patent networks have been extensively analyzed at the level of individual inventor, inventor team or applicant organization. Inter-organizational patent networks are mainly analyzed in light of uncovering knowledge transfer dynamics (Chakrabarti et al. 1993; Singh 2005; Li et al. 2007). Importantly, Cassiman et al. (2010) find that firms with scientific collaborations perform better than organizations with no scientific linkages. Besides, patents from companies with strong links to the science community appear to have a larger impact than 'solo' patents (Cassiman et al. 2010). With regard to the heterogeneity characterizing high-technology industries, Balconi et al. (2004) find that academic inventors play a more central role in the patent network than their non-academic peers. This means that academic inventors act as important brokers of information and play an important role in bringing together research teams from different institutions or companies.

In sum, we use the BoD-network as a representation of the strategic network in the region's biotechnology industry while the patent network uncovers the innovation network. The following section introduces our empirical case and the methodology applied to answer our research question.

6.3 Data

The subject of analysis is the Flanders and Brussels biotechnology industry, the part of the Belgian biotechnology industry that is characterized by the presence of top research institutes, thriving start-ups and academic spin-offs in a large set of biotechnology application fields (Nauwelaers 2007). As Belgium is among the top countries in biotechnology innovation and industry performance (OECD 2006), this subject of analysis may therefore serve as a good practice example, allowing us to draw conclusions and formulate policy implications relevant for other regional biotechnology industries.

Our population consists of all biotechnology organizations involved in life sciences R&D and/or -production in Flanders and Brussels (as 1–100 % of their activities), using the OECD's list-based definition of the modern biotechnology (OECD 2005). The list was obtained from Flandersbio, the region's industry umbrella organization. Adding the region's academic hospitals has resulted in a research population of 148 organizations.¹

The composition of the board of directors for all organizations was retrieved from their financial statements (2007). The 148 organizations count 1020 board positions (an average of 7.5 directors per organization), held by 915 persons. A vast majority (837) is director in one organization, while 78 directors are a member of at least two biotechnology organization boards.

In a next step, we selected all international patent applications between 2004 and 2011 in which at least one organization from our population was listed as an applicant. We found that 66 out of 148 organizations (44.6 %) patented their innovations during the selected time interval. On a total of 1,373 biotechnology patent applications, 249 (18.1 %) are shared between two or more organizations. In total, 22 organizations (14.9 % of population) are present in the patent network and thus share at least one patent with another organization from our population. We selected this time frame since the composition of the BoD-network is a unique emergent property of an industry, stable over time and resilient to major changes in policies, director turnover or industrial trends (Davis et al. 2003). Furthermore, BoD-positions in Belgian organizations are typically allocated for 5 or 6 years. Consequently, we can assume that the BoD-network was stable in the period 2004–2011, which allows us to gather enough data on joint patenting activities.

In Fig. 6.1, we give a visual representation of the BoD-network infrastructure of the studied biotechnology industry. This BoD-network infrastructure is a subset of the complete BoD-network as it only takes into account the interlocked directors and connected organizations, leaving aside unconnected organizations and directors with only one board position. We observe that the BoD-network of the Flanders and Brussels biotechnology industry consists of ten 'components', a term used to indicate the independent structures of interconnected organizations (numbered 1 through 10 in Fig. 6.1). Component 1 is clearly the 'largest connected

¹ Original dataset is available upon request.

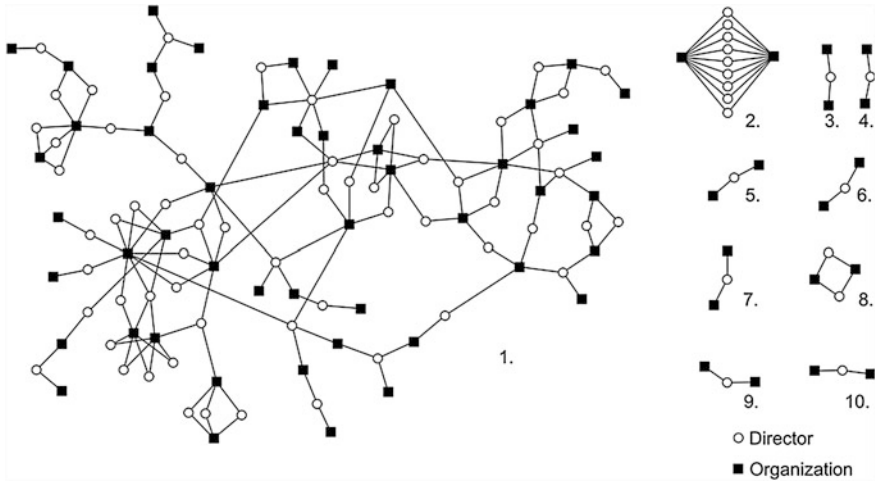


Fig. 6.1 The BoD-network infrastructure of the Flemish and Brussels Biotechnology Industry, own set-up

component’ of the given industry as it contains most network actors of all components. The other components, numbered 2 through 10, consist of two organizations that are connected by at least one interlocked director.

Figure 6.2 shows the patent network infrastructure of the Flanders and Brussels biotechnology industry. Again, we only take into account the organizations that share a patent application and the shared patents to draw this network. Interestingly, this network infrastructure consists of only one component, showing no other independent structures of interconnected organizations. This indicates a strong inter-organizational collaboration on innovative projects in a specific segment of the industry, and a lot of isolated innovation activities in other segments of the industry.

6.4 Methodology

In this section, we describe the methodologies used to answer our research question: How similar are the strategic network and the innovation network in the biotechnology industry? We use a Jaccard-coefficient to measure how similar the portfolio of an organization’s connections is in both networks. We complement this analysis by looking at the strength and by identifying the key players of the networks using measures for node centrality and power. We use UCINET Software, version 6.380 to perform the network analyses (Borgatti et al. 2002; Hanneman and Riddle 2005).

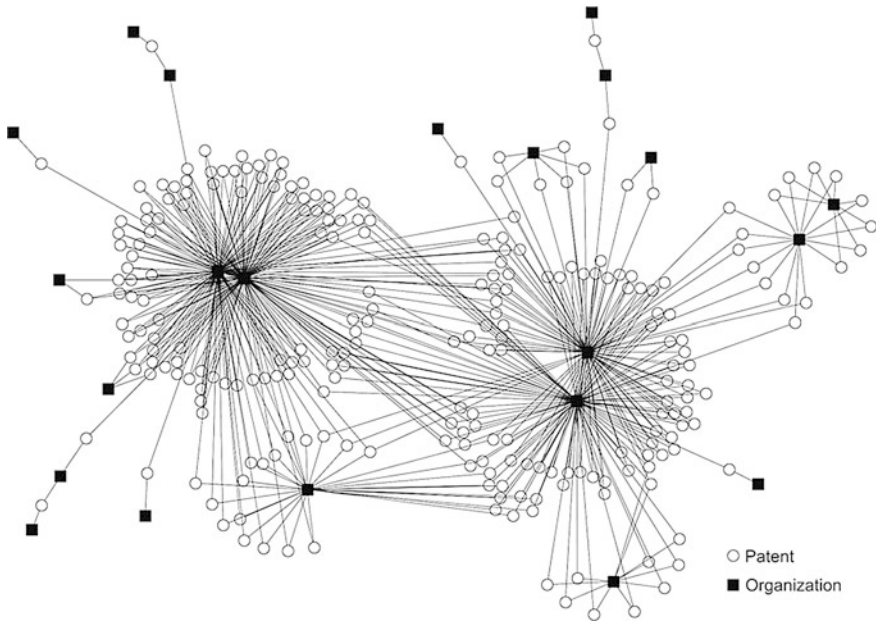


Fig. 6.2 The patent network infrastructure for the Flemish and Brussels Biotechnology Industry, own set-up

6.4.1 Similarities Measurements

This study entails two types of networks consisting of the same organizations. We investigate the similarity of these actors based on their ties to other organizations in the respective networks. To assess the similarity, we calculate the Jaccard-coefficient which calculates the number of times an actor possesses a tie to the same actor in both network infrastructures as a percentage of the total number of ties reported (Hanneman and Riddle 2005; Liben-Nowell and Kleinberg 2007). We calculate the Jaccard-coefficient as follows:

$$score(x, y) = \frac{\Gamma_{(x)} \cap \Gamma_{(y)}}{\Gamma_{(x)} \cup \Gamma_{(y)}}$$

with $\Gamma_{(x)}$ being the set of linked organizations in network X (BoD-network) and $\Gamma_{(y)}$ being the set of linked organizations in network Y (Patent network). This leaves us with an index that indicates the relative importance of shared relations in both networks with 0 indicating no shared relations, and 1 indicating that only shared relations exist. Standard errors to test measurement significance are based on a simulation based quadratic assignment procedure (Borgatti et al. 2002; Hanneman and Riddle 2005).

6.4.2 Node Centrality and Power

In order to investigate the strength of the network and to identify key players in both networks, we look at a number of network characteristics.² First, strong networks contain a large number of hubs. These hubs are actors in a network that are connected to many other actors and thus have a central role in the diffusion of information and knowledge (Giuliani and Bell 2005). Second, strong networks are characterized by a high degree of clustering (Watts and Strogatz 1998; Conyon and Muldoon 2006, 2008). Clustering is the extent to which actors in the network have a strongly overlapping circle of common connections. This means that clustering quantifies the different ways in which knowledge can flow from one node to another. Third, in strong networks the distance between nodes is short (Watts and Strogatz 1998; Conyon and Muldoon 2006, 2008). Distance is the number of steps it takes on average to get from one actor in the network to another. If the distance is short, a short chain of acquaintances links the network actors and knowledge can spread rapidly throughout the network (Davis and Greve 1997; Watts and Strogatz 1998; Davis et al. 2003; Baum et al. 2004; Conyon and Muldoon 2006, 2008).

To measure these concepts and to characterize networks, we use the three measures as introduced by Freeman (1979): ‘degree centrality’, ‘closeness centrality’ and ‘betweenness centrality’. In this way, we can identify the critical nodes in the network, thus revealing the key players and powerful hubs in the strategic and innovation networks.

Degree centrality measures the number of ties that connect a node to other network actors. A high degree indicates the extent to which an organization can act as a hub in the network (Freeman 1979). The degree centrality however does not consider the global structure of the network, an element that is rather measured by closeness centrality.

Closeness centrality measures the distance, i.e. the number of edges separating a node from all other nodes of the network, for all nodes in the network. We calculate this measure using the reach-based centrality and closeness centrality for both networks (Borgatti et al. 2002; Hanneman and Riddle 2005). The more central a node based on this index, the shorter its relative distance to all other nodes.

Betweenness centrality quantifies to what extent a node is part of the geodesic paths (shortest paths) between other pairs of nodes from the same network. A high measure for a node, indicates that this actor possesses a high degree of control over the information flow in the network (Freeman 1979).

² Importantly, we narrow down our analysis towards these organizations present in the network infrastructure, thus omitting organizations that are not connected to the BoD- or patent network.

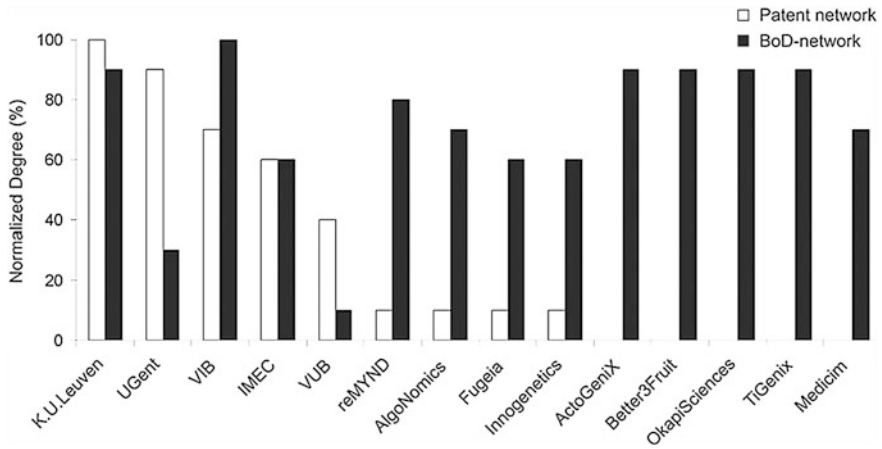


Fig. 6.3 Normalized degree centrality per organization, Top-5 organizations in the BoD-network (*black*) and the patent network (*white*)

6.5 Results

First, we assess the similarity between both the BoD-network and the patent network. Next, we compare the key actors in the networks, namely organizations with a high degree centrality or closeness centrality in the different networks.

Calculating the Jaccard-coefficient, we find a high and significant 4.5 % similarity between the BoD-network and the patent network of the Flanders and Brussels biotechnology industry. The average random similarity between the two networks, based on the simulation procedure, is 0.2 % (std. dev. of 0.4 %). As extreme low densities characterize the networks studied, expected co-occurrence of relationships in both networks is also very low (e.g. only 2 % of shared connections could be expected). As a result, a strong and significant probability is found (more than 6 standard deviations) that when a connection in the BoD-network exists, these interlocked organizations also share at least one patent. We are not able to draw conclusions with regards to the causal direction of this relation. However, this result suggests that when knowledge transfer happens through BoD- and/or shared patent networks, it is more likely that it happens simultaneously through both networks. In order to further explore and theorize this phenomenon, we compare in the remainder of this section those biotechnology organizations that possess a central position in both networks.

To compare the degree centrality of the organizations in both networks, we select the five organizations with the highest normalized degree centrality in both networks. The results are presented in Fig. 6.3. The white bars represent the organization's normalized degree centrality in the patent network and the black bars represent the normalized degree centrality in the BoD-network.

We observe that KU Leuven, VIB and IMEC are the only three organizations characterized by a high degree centrality in both networks. In both networks, these organizations hold advantageous positions and are in a position to influence knowledge flows in both networks. This also suggests that these organizations possess an efficient and effective information flow between the strategic and the operational levels. Given the literature on biotechnology innovation and the central role for academic centers of excellence in the industry, it comes as no surprise that these three central organizations are academic institutions. However, we notice that Ghent University and Vrije Universiteit Brussel are two major academic players in the patent network, while these organizations do not possess this position in the BoD-network. We furthermore observe that there are several companies with a high degree of centrality in the BoD-network, yet none are characterized by a similarly high degree of centrality in the patent network, which is clearly dominated by a number of research institutes from the region.

Figure 6.4 presents the organizations characterized by the highest normalized reach-based centrality in both networks (top five). The white bars indicate the organization's normalized degree of closeness (centrality) in the patent network, while the black bars to indicate the normalized degree of closeness in the BoD-network.

The results on closeness centrality confirm the results obtained from the degree centrality comparison. Academic research institutes in the network infrastructure play a central role in both networks. Some smaller firms possess a strong position in the BoD-network, without necessarily showing a strong position in the patent network.

In both the BoD- and the patent network, we observe large variations in the betweenness centrality measure. Moreover, in the patent network, structural constraints prevent us from calculating a useful and reliable betweenness centrality measure. Therefore, we exclude this measure from our analysis.

In sum, players with the highest centrality—VIB, K.U. Leuven, IMEC, and to a lesser extent Ghent University—are key players in both the strategic and the innovation network. These organizations have easier access to other organizations in the biotechnology industry and can influence the knowledge flowing through both of these networks.

6.6 Discussion and Conclusion

Balconi et al. (2004) already indicated the importance of academic inventor networks in science intensive industries. They suggested that these powerful inventors serve as 'inventor brokers', acting as connection between different research groups. We find support for this proposition at an organizational level, but also observe that a number of research institutes in the region are neither present nor powerful in the networks scrutinized. This may indicate that some research organizations have capabilities to combine a powerful position in the network that

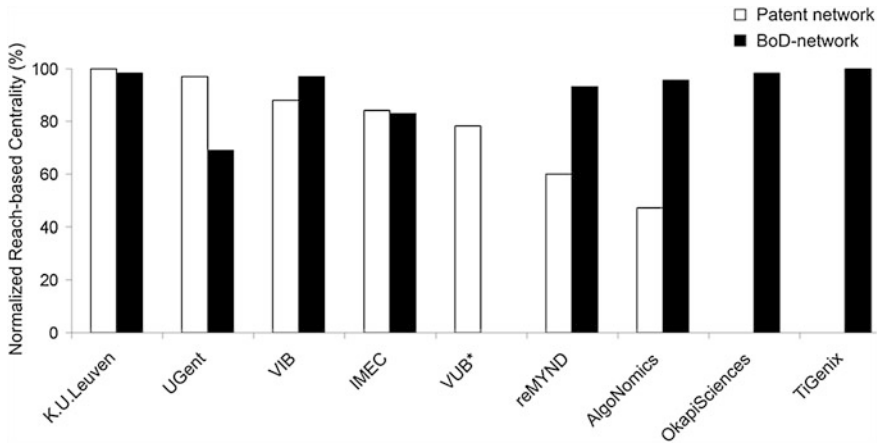


Fig. 6.4 Normalized reach-based centrality per organization, Top-5 organizations in the BoD-network (*black*) and the patent network (*white*). Reach-based centrality in the BoD-network was not calculated for VUB since this organization is not part of the main connected component, rendering the analysis of this measure useless

transfers science and technologies (patent network) as well as in the network that transfers knowledge on management and governance (BoD-network). In many ways, it is not surprising to find universities and biotechnology research institutes at the heart of the innovation network. But these institutes also access the BoD-network to use it as an essential platform and information-accessing tool with regard to knowledge on academic commercialization (Pusser et al. 2006). This indicates that institutes in a more favorable position in the innovation network will more easily access external knowledge and recognize opportunities. This access provides them with an increased stock of technologies that may be commercialized in a next stage. Furthermore, we notice that the smaller and more diversified institutions fall out of the networks, which may be due to a lack of critical mass or research scope. Future research should confirm these propositions (Fig. 6.4).

Interestingly, in the BoD-network, another type of key player emerges: the academic spin-offs. These new firms are built around intellectual property and technologies originating from the institution's laboratories (e.g. Tigenix, Fugeia, Actogenix). Close linkages with their parent institution characterize academic spin-offs. These linkages are often maintained as a means to access scarce resources. Hence, spin-offs' networking activities, not only with universities but also with customers and suppliers, are important for their future success (Pérez Pérez and Sanchez 2003; Lindelöf and Löfsten 2004). We observe that the linkages of spin-offs to the scientific community are more prominent in the strategic network than they are in the innovation network. While academic spin-offs are indeed well provided with knowledge on the insourced technology, they may need the access to the parent university's BoD-network so they can access knowledge on the commercialization of academic knowledge. Accessing inter-organizational

networks may, in addition, act as a signal of quality for new firms (Zaheer et al. 2010). This appears to be very important in the biotechnology industry, where technology companies tend to address independent directors, experienced CEOs and investors, to validate their technology and company.

Looking at the key players and composition of both networks, we observe an absence of large industrial conglomerates in both networks. Traditional R&D powerhouses such as pharmaceutical companies or chemical concerns are apparently less prone to access the regional strategic and innovation networks. It is likely that these firms access similar networks, but on an international level. This practice would however conflict with studies stressing the importance of physical proximity in innovative industries (Arundel and Geuna 2004; Boschma 2005).

A last remark concerns the structural characteristics of both network infrastructures. We observe that the networks are characterized by a prominent 'largest connected component', which groups the most important players in the regional biotechnology industry. In the BoD-network infrastructure, we observe a couple of other small components, while in the patent network we observe no other components than the main one. This means that at both levels, there exists a highly networked population of core players and a large group of unconnected organizations, which are excluded from the benefits and opportunities arising from participation in the studied networks.

In this study, we investigate to what extent the strategic network and the innovation network in the biotechnology industry are similar. We find that a connection between two organizations in the strategic network increases the probability of forming a new connection between the same organizations in the innovation network, or vice versa. This means that collaborations between two organizations on one network level can lead to an interlocking of the organizations at other network levels. Further research should clarify whether this dynamic stems from a need to minimize coordination costs or whether this is caused by effective knowledge flows between different levels within biotechnology organizations. In this case, organizations possessing superior internal communication capabilities align their partners at the different levels and achieve synergies between their strategic and innovative activities. Our results also suggest that very few companies establish and maintain a strong position in the biotechnology innovation network. This network is clearly dominated by academic institutions, which are the key producers of scientific knowledge. The BoD-network has a more balanced composition/power structure and knowledge on strategic issues is transferred across a wide range of industrial actors, including research institutes. This indicates that these institutes transfer technology in a unidirectional way (e.g. from university to spin-off), but at the same time need to access external strategic knowledge via other routes. Additionally, we observe that academic spin-offs are powerful players in the regional strategic network. Together with the observation that large pharmaceutical companies and smaller diversified universities are to a large extent absent in the networks, we propose that being part of these inter-

organizational networks is influenced by the organization's origin, scope and size. This calls for a more thorough investigation on what influences the composition of BoD-networks (see also Crispeels et al. [in press](#)) and patent networks.

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