NETWORK EMBEDDEDNESS AND NEW VENTURE INTERNATIONALIZATION: ANALYZING INTERNATIONAL LINKAGES IN THE GERMAN BIOTECH INDUSTRY

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Abstract

This paper examines whether inter-organizational factors influence German biotech firms' propensity to internationalize by forming international research alliances. Inter-organizational factors include dimensions of a firm's embeddedness within its local cluster and within its national research network. We test two sets of hypotheses (local and national network-drivers) on a longitudinal event history dataset of the complete German biotech population for the years 1995-2004. Findings show that location in a local cluster already dense with international linkages, the building of research alliances with local research institutes as well as national partners and central position in the national research network increase the probability of forming international research alliances.

1. Executive Summary

Within the last decade there has been evidence of early internationalization of new ventures, especially those in high technology industries. In this paper we explore why new technology ventures enter international research alliances. Previous research has examined the factors that fuel international expansion, including institutional factors (i.e. regulations), industry factors (i.e. competitive intensity), and organizational factors (capabilities and knowledge). Surprisingly little research has analyzed the role of different types of ties for the internationalization of new ventures. Particularly lacking are studies of the effect of the actors' location within a venture's network of ties on the probability that it will internationalize. To fill this gap, this study examines two sets of hypotheses linking new ventures' embeddedness in the local cluster and in national-level networks to the probability of internationalizing via international research alliances. Our dataset is the complete German biotech population for 1995-2004.

Our first set of hypotheses links dimensions of local embeddedness within a cluster with a new venture's probability of internationalizing via international research alliances. Results show that firms located in clusters with higher "international alliance intensity" (more prior international alliances per member firm) have a higher probability of forming international research alliances. We explain this finding in terms of knowledge spillovers a biotech firm can entail from internationally linked local organizations. By virtue of knowledge spillovers, firms are able to reduce their knowledge gap regarding

potential foreign partners as well as regarding the specifics and challenges of forming an international alliance. Also a firm's probability of forming international alliances is positively associated with the number of prior links it has with local research institutions. It seems that firms with links to local knowledge centers are attractive alliance-targets for foreign partners. However we found no effect of the cluster's "simple density with public research institutions" (number of public research institutions within the cluster) or the "organizational diversity" of the cluster (diversity in terms of types of organizations in the cluster) on the probability of forming international alliances.

Our second set of hypotheses concerns the effect of embededdness in national-level networks on the probability of venture internationalization via research alliances. The findings show that the number of prior national research alliances of the focal firm increases its probability of entering into an international alliance. To explain this finding we suggest that prior national alliances lead to generalized "alliance capabilities" with geographically remote partners, which are helpful for international alliance formation. We also found that firms with a more central position in the national network have a higher probability of forming international alliances. Central firms (those that are allied with more and better connected partners), signal trustworthiness which encourages a favorable evaluation by a potential foreign partner.

Our research has several implications for managers of new ventures. First, new ventures that target internationalization should locate in "internationalized" clusters in order to benefit from local knowledge spillovers and signaling effects. Second, new ventures have to develop linkages at the national level. Such national cooperations are a prerequisite for international alliances because they offer an arena in which the firm can develop alliance capabilities. Second, the centrality of the firm within the national network seems to be of great importance not only in building these capabilities, but also in attracting international partners. Therefore, new ventures should try to take a central role in the national network from the outset, for instance by allying with high status biochemical or pharmaceutical firms.

2. Introduction

Within the last decade there has been evidence of early internationalization of new ventures, es-

pecially those in high technology industries (Oviatt & McDougall, 1994; Autio, Sapienza and Almeida, 2000; Zahra and George 2002; Coviello and Jones, 2004). The observation that these firms engage in cross-border activities from their inception poses an interesting challenge for the established body of theory in the area of international management. New ventures have fewer resources and less international experience and know-how than large multinational enterprises (Li, Li and Dalgic, 2004).

One of the most recent definitions of "international entrepreneurship" is the "discovery, enactment, evaluation and exploitation of opportunities - across national borders - to create future goods and services" (Oviatt and McDougall, 2005). A common mode of internationalization for new technology ventures (especially in biotechnology) is the formation of international research alliances (Hagedoorn, 2002); they are vehicles of "discovering, evaluating and exploiting technological opportunities across national borders". In the longer term, there is evidence that international research alliances increase the firm's potential for further international expansion in terms of sales (Leiblein and Reuer, 2004).

Surprisingly little research so far has analyzed the role of different types of ties for the internationalization of new ventures (Jones and Coviello, 2005; Zahra and George, 2002; Autio et al. 2000). Particularly lacking is investigation of the effect of the location of the actors within a venture's network of ties on its probability of internationalizing. Within the broader field of international management, the influence of location on firms' internationalization has recently been identified as an important, yet understudied research topic (Buckley 2002, p. 369). The question whether local ties within a local cluster and/or 'remote' national research-ties are conducive to firms' internationalization via international research alliances remains empirically unaddressed so far and constitutes the core theme of our paper.

We draw on Gulati and his associates' work on alliances (Gulati, 1995b; Gulati, 1999; Gulati and Gargiulo, 1999) who argued that network enlargement is a dynamic process based upon prior ties; we examine two sets of hypotheses linking a biotech firm's cooperative ties on the local and on the national level to the probability of internationalizing via forming international alliances. Rather than seeing the local and national forms of embeddedness as mutually exclusive we assume that they are complementary and beneficial for a biotech firm's internationalization. We test the hypotheses on a longitudinal event history dataset of the complete German biotech population for 1995-2004.

This study contributes to the literature in several ways. Firstly, we extend research on international entrepreneurship by highlighting the importance of networks as a driver of internationalization via research alliances – specifically distinguishing local from national ties. Secondly, we extend both the alliance and the international entrepreneurship literatures by focusing on the effect of cluster location on formation of international research alliances. Empirical studies on the link between clustering and internationalization are limited (Zahra and George, 2002 – see Coombs et al., 2006 for a recent exception). Thirdly, our differentiation between local and national ties extends the contingency perspective in organizational networks. Gulati and Higgins (2003) argued that different types of ties matter differently and that we do not know enough about the contingency value of ties in organizational networks. Fourthly, we enhance the network literature by attempting to predict international network development (international alliances). Network studies with network development as the dependent variable are scarce (Hoang and Antoncic, 2003; Gulati 1999). Finally, we make a methodological contribution by using longitudinal data from a complete population. Longitudinal studies are needed in both the international entrepreneurship (Coviello and Jones, 2004) and the network literatures (Hoang and Antoncic, 2003).

3. Theory and hypotheses

Within the new field of international entrepreneurship (for recent reviews, see Dimitratos and Jones, 2005; Coviello and Jones, 2004; Zahra and George, 2002), research has examined the antecedents (e.g. Chen and Martin, 2001; Oviatt and McDougall, 1997), processes (e.g. Oviatt and McDougall, 1995) and performance effects of new ventures' internationalization (e.g. Reuber and Fischer, 2002; Bloodgood, Sapienza and Almeida, 1996; McDougall and Oviatt, 1996). Internationalization seems to positively influence new ventures' survival, profitability, and growth (Oviatt and McDougall 1997). Furthermore, by internationalizing, new ventures acquire knowledge that can be used to build additional value-creating skills (Zahra and George 2002, Barkema and Vermeulen 1998).

In particular, our research focuses on internationalization via international research alliances. McDougall and Oviatt (2000) included co-operative alliances as one of the key topics within the domain

of international entrepreneurship. Why are international research alliances a mode of internationalization, especially for high-technology industries? Often the value creation of the firm is based on a cross-border combination of valuable resources (such as technical knowledge). In this case, the firm needs to internationalize to create value (e.g. to develop a product), not to disseminate its outputs (Autio 2005). The alliance literature labeled such collaborations "exploration alliances" (Grant and Baden-Fuller, 2004; Rothaermel and Deeds, 2004). International exploration alliances are important as a mode of internationalization for biotechnology, due to the intense international competition for knowledge and intellectual property (Hagedoorn and Roijakkers, 2002; Powell et al., 1996).

What do we know about new ventures' motivations to internationalize via formation of international alliances? The alliance literature informs us that firms enter into alliances for a number of reasons such as to share risks, capital, technology and firm-specific assets (Gulati, 1999, 1998). Alliances provide a number of advantages especially to new ventures (Baum and Silverman, 2004), primarily associated with access to complementary resources (Chung et al., 2000) and knowledge (Liebeskind et al. 1996). Alliances may also confer an aura of legitimacy (Baum and Oliver, 1991). However, there are limits and risks to alliance usage (Alvarez and Barney, 2001; Rothaermel and Deeds, 2004). Overuse of alliances can create complex administration and coordination problems. Research alliances may leak technological knowledge allowing competitors to imitate innovation (George et al., 2002; Gulati, 1995a). Overall, firms develop international alliances to draw upon country-specific knowledge (Almeida et al., 2002) that can be used for exploration or exploitation (Coombs et al., 2006).

The international management literature also examined the factors that fuel internationalization, namely institutional factors (i.e. regulations), industry factors (i.e. competitive intensity), and organizational factors such as knowledge and resources (Zahra and George, 2002). Some research has also recognized that, by virtue of network embeddedness, firms can overcome their resource and knowledge constraints and internationalize in a manner not possible for an isolated firm (Zahra, Ireland and Hitt, 2000). Johanson and Mattsson (1988) suggested that a firm's success in entering new international markets is more dependent on its relationships within current domestic markets than on characteristics of the new market. In essence, social capital from prior relationships influences the formation of new rela-

tionships in the following time period (Gulati, 1999; Walker et al., 1997). As noted earlier our paper extends our limited knowledge of the relationship between networks and internationalization, with a more specific focus on the effect of the location of different actors within a new venture's network.

An average international research alliance has two partners – a local new technology venture partner (in our case a young German biotech firm) and an international partner (e.g. another biotech venture or a large pharmaceutical or biochemical firm). Usually one of the two partners initiates the alliance by identifying and targeting the other. To theoretically explain the effect of young firms' research networks on their probability to form international alliances we look at the issue from two perspectives: how do networks help the local new-venture partner to initiate an alliance (identify, convince and manage the international partner)? and how do networks make the local new-venture partner look more attractive, so it gets selected by an international partner who is looking for an alliance?

From the perspective of the local new-venture partner initiating an international research alliance, we suggest that, in a broad sense, the embeddedness in research networks can increase the alliance probability in two ways: first, by offering information about the benefits of internationalization and about potential international partners and second, by providing experience to the local new-venture partner to initiate and manage research alliances (alliance capabilities). Reverting to the perspective of the international partner initiating an international research alliance, we suggest that research networks of the local partner can also increase the alliance probability in two ways. First, by enhancing the local new-venture's access to technical knowledge, therefore making it a technically attractive partner. Second, by increasing the visibility of the local firm as a reliable alliance partner (signaling and reputation effects). The study's conceptual model and hypotheses are presented in Figure 1.

-Figure 1 about here-

3.1 Benefits from local embeddedness

Our first set of hypotheses deals with the effects of a new venture's embeddedness in the local cluster on its probability of internationalizing via research alliances. A cluster is defined as a geographic concentration of economic and organizational activities (Folta et al., 2006) and in simple terms is a

group of similar and complementary firms located close to one another (Stuart and Sorenson, 2003). A growing body of research points to the economic benefits of geographic clustering. Results by Audretsch and Feldman (1996), Porter (1998), Pouder and St. John (1996) and Krugman (1991), based on the seminal work by Marshall (1920), provide a rationale for local clustering based on the benefits of labor pooling, specialized suppliers and "knowledge spillovers". This latter term describes the transmission of sticky, non-articulated, tacit forms of knowledge between firms (Batheld et al., 2004).

However, there are limits to clustering benefits. "Diseconomies of agglomeration" may take the form of congestion costs, which increase with the size of the cluster (Prevezer, 1997). As clusters grow big, competition and prices for workers, for land and for utility services increase (Folta et al., 2006; Stuart and Sorenson, 1993). Folta et al. (2006) reconciled the opposing views of economies and diseconomies of agglomeration by suggesting increasing returns to cluster size at the beginning but an increasingly important role of diseconomies of agglomeration as clusters evolve. In this paper, we study the emergence of the German biotech industry in its first years and therefore we focus on the benefits of clustering, assuming that the diseconomies of agglomeration are not part of the picture yet.

Do the clustering benefits also affect the probability to internationalize via research alliances? The literature is scarce on this topic but there are some early indications. Dunning (1998) observed that local clusters and networks are among the factors that are increasingly influencing internationalization patterns. Coombs et al (2006) found that the location of a biotechnology firm in a technologically munificent cluster is a significant determinant of allying with international financial partners. They interpreted their findings as indications that international firms form financial alliances with entrepreneurial ventures in locations in which desirable knowledge spillovers can be expected. Knowledge spillovers occur through formal and informal channels of communication among employees (Deeds et al., 2000). Informal mechanisms include mobility of personnel, social and trade meetings. Firms can learn from each other informally by being a part of the "localized buzz" of their cluster (Batheld et al., 2004). In contrast, formal mechanisms of knowledge spillover include direct collaborations such as licensing, acquisitions and alliances. We will address both types of mechanisms in turn.

3.1.1. "Informal" benefits from cluster characteristics favorable to internationalization.

By operating alongside other organizations with international linkages, cluster firms would be more capable of learning about the possibilities that exist internationally (Coviello and Munro, 1997). We would expect them to benefit from knowledge spillovers about foreign market opportunities and challenges. We would also expect them to learn from the alliance experience of internationally connected organizations, helping them to identify and evaluate potential alliance partners for their own internationalization strategy. This information-advantage argument has been core to the alliance literature (Gulati, 1999). The informal network of cluster firms with prior experience with international alliances becomes a growing repository of information on the availability, competencies and reliability of potential partners (Gulati and Gargiulo, 1999). Therefore, we suggest that by locating in clusters with high "international alliance intensity" (defined as the average number of prior international alliances per cluster firm) new ventures can initially recognize the benefits of internationalization and subsequently identify and convince international partners to form research alliances, benefiting from informal knowledge spillovers. Moreover, from the perspective of the international partner initiating the alliance, the international alliance intensity in a particular region has a signaling effect and attracts more potential international partners (Lowe and Gertler, 2005). Consequently, we pose the following hypothesis:

Hypothesis 1a. The greater the regional cluster's international alliance intensity, the greater the probability that a new venture will internationalize via international research alliances.

The literature suggested that the regional concentration of international firms is partly due to the availability of the competences sought (e.g. technical knowledge tends to be concentrated in certain regions, see Dunning, 1998). The "knowledge based view of the firm" has argued that the international expansion strategy is driven by knowledge-based considerations (Kogut, 2000; Grant, 1996). Internationalization can be a means to gain access to knowledge and capabilities firms do not possess. In other words, when international firms assess potential research partners in the host country, they are usually after technical knowledge. According to the agglomeration literature, location within a research-active cluster facilitates localized knowledge diffusion (Arndt and Sternberg, 2000; Markusen, 1996) and po-

tentially increases a new venture's stock of technical knowledge. But what drives the development of such research active clusters? Public research institutions are often the engines behind a cluster's research activity (George et al., 2002). Gittelman and Kogut (2003) argued that co-location with research centers is a requirement for success in the biotechnology industry. Therefore, we suggest that location of a new venture in a cluster with high "simple density with public research institutions" (defined as the number of public research institutions within the cluster) signals to the international firm a knowledge-rich and hence attractive local partner, raising the likelihood of an international research alliance. We hypothesize:

Hypothesis 1b. The greater the regional cluster's simple density with public research institutions, the greater the probability of a new venture internationalizing via international research alliances.

Examples from several countries show that over time local clusters attract a variety of organizational types and forms (Lowe and Gertler, 2005). The configuration of a regional cluster is driven by collocation decisions of technical suppliers, research institutes, financial institutes, professional service firms (such as IT-companies and consultants) and clients (such as biopharmaceutical firms), who are attracted by the opportunities that the cluster offers (St. John and Pouder 2003). Findings by Lowe and Gertler (2005), St. John and Pouder (2003) and Mariotti and Piscittello (2001) point to co-evolutionary and mutually reinforcing processes in the founding of core and supporting organizations, which, over time, shape the structural configuration of the cluster. In a study of Canadian biotechnology clusters, Lowe and Gertler (2005) found the diversity of organizations within a cluster to be a major driver of growth and innovativeness of local firms. Similar results have been found in US and UK biotechnology clusters (Prevezer 1998; Shohet 1998). As a result of the collocation processes of diverse organizations, a regional cluster will develop its own distinctive resource and localized capability profile (regional specialization). Based on these arguments, we suggest that the "organizational diversity of a cluster" (defined as the diversity of organizations represented in the cluster) makes a cluster more attractive to international partners and increases the probability of internationalization of local firms via international alliances.

Hypothesis 1c. The greater the organizational diversity of a new venture's regional cluster the greater its probability of internationalization via international research alliances.

3.1.2. "Formal" benefits from collaborations within the cluster

The previous hypotheses predict that international firms generally prefer certain types of clusters, but do not inform us about which firms are particularly likely to be selected from within a cluster. Our argument can be refined to include formal collaborative links (research alliances) as predictors of further international research alliances. Gulati's research (1995a) has shown that there is greater distrust between partners when forming cross-national alliances. The embeddedness of the national partner in a regional network can signal trustworthiness and reputation, "because the reputational consequences of opportunistic behavior are greater in a domestic context" (Gulati 1995a: 95).

Suppliers of scarce resources (such as international partners) are more likely to choose a new venture partner if it is *directly* backed by a credible third party whom they trust (Powell et al., 1996) and offers a signaling value (Gulati and Higgins 2003; De Carolis and Deeds, 1999). Formalized ties to local research institutions can play this signaling role. Relationships with established and reputable local research institutions can enhance a new venture's legitimacy in the eyes of the international partner (Gulati and Higgins, 2003).

In addition, such relationships can make the new venture a more attractive partner by increasing its direct access to technological knowledge and resources (George et al., 2002; Mian, 1997). Zucker et al. (1998) argued that knowledge does not transfer via informal spillovers but through direct collaboration. Moreover, alliances with local research institutions can act as a learning ground for new ventures and increase their capabilities to develop and organize alliances (Gulati, 1999). As the new venture becomes more proficient in identifying and attracting alliance partners, it has more chances of developing research alliances with international partners interested in the cluster (George et al, 2002; Gulati, 1999). Therefore, we suggest:

Hypothesis 1d. The greater the cumulative number of prior local research alliances of a new venture with public research institutions within its cluster, the greater its probability of internationali-

zation via international research alliances.

3.2 Benefits from research ties at the national level

Our second set of hypothesis draws upon the observation that there might be limitations to the benefits of spatial proximity. We see a potential limitation in the incompleteness of knowledge and other crucial resources within the local cluster. Since the German biotech industry is still quite young, we expect certain crucial knowledge to be missing locally. Clusters might be incomplete in terms of the types of supporting organizations, or clusters might be too young to have developed that synergistic profile described above. Therefore the locally available advantages may not be sufficient to attract foreign firms, and biotech start-ups may be unable to benefit from local knowledge spillovers. Empirical evidence from Canadian biotech cluster studies suggest that successful firms "are more likely to be deeply imbedded in continental and global knowledge networks and production systems" (Wolfe et al. 2005: 10).

Kogut and Walker (2001) showed the importance and the durability of national networks, using Germany as an example. Ownership links among German firms constitute a "small world", which represents a network with closely-knit clusters of firms that are nonetheless highly connected across the national network by a small number of intermediaries (Watts, 1999). "Small world" structures, based on national systems of power, are persistent and replicate themselves despite disruptions from the penetration of global firms. National networks mediate global and local forces and provide specific actors (intermediaries) with the resources and opportunities to preserve the national structure (Kogut and Walker, 2001). We therefore argue that new ventures' research alliances at the national level, complement local ties and foster internationalization via research alliances.

We first expect benefits from the number of prior national research alliances the new venture has formed. Second, we believe that the new venture's position within the overall national network has an important impact on resource flows, and therefore on internationalization outcomes (Hoang and Antoncic, 2003). We will address both measures in turn.

3.2.1. Benefits from the number of prior national research alliances of the focal firm

Within the alliance research stream, several challenges for firms in managing learning alliances and accessing capabilities of partners have been emphasized (e.g. Grant and Baden-Fuller, 2004; Khanna et al., 1998). Research has confirmed the time-consuming, complex and insecure character of the learning process, emphasizing especially the challenge of gaining access to partners' tacit and sticky knowledge (von Hippel, 1998). Geographical distance and cultural differences seem to exacerbate this problem in international alliances. Successful learning within international alliances depends upon certain conditions, such as face-to-face interaction (Inkpen and Crossan, 1995).

In mitigating these challenges, the need to develop "alliance-capabilities" has been recommended. By providing valuable information (Gulati, 1995a, b) experience with cooperation (Walker et al, 1997) and procedural knowledge of how to manage alliances (Kogut and Zander, 1992) prior alliances play an important role in shaping the formation of future alliances. Repeated alliance engagements over time contribute to the build-up of an alliance management capability (Dyer and Singh, 1998; Gulati, 1999; Rothaermel and Deeds, 2006). This means that the more relationships a firm has, the more it knows about how to manage them so the less costly it is to form new relationships (Walker et al., 1997).

We suggest that allying with "remote" partners at the national level provides different and more important benefits than local research alliances, in terms of creating alliance capabilities. Walker et al. (1997) noted that managing partners across regions is a more complex task than managing partners from the same region. Firstly, it is more difficult to initiate collaborations with geographically remote firms than with local ones, due to the lack of prior interaction in the local area, which would provide deeper knowledge about the actors' reliability and specific needs. Secondly, it is harder to manage alliances with remote rather than local partners, due to the lack of the natural trust and understanding created by the everyday face to face communication during a project. Consequently, allying with geographically remote national partners is a more similar activity to an international alliance than allying with local research institutions. Therefore, we suggest that by experiencing multiple national research alliances, the new venture builds the necessary types of capabilities to form international alliances. Moreover, from the international partner's point of view, a firm with multiple alliances at the national level makes

an attractive partner as it signals better access to technical knowledge and better reputation. Thus, we pose the following hypothesis:

Hypothesis 2a. The greater the cumulative number of prior national research alliances of a new venture the greater its probability of internationalization via international research alliances.

3.2.2. Benefits from a focal firm's prominent network position

The number of relationships, however, does not fully capture a firm's position within a greater social structure. In simple terms, having many contacts is not equal to having the right contacts. The social network literature suggests that the position of an actor in a social network can indicate the importance (or synonymously prominence) of the actor (Perry-Smith, 2006; Gulati, 1999). Actors are defined as "prominent" if their ties make them particularly visible to other actors in the network (Wasserman and Faust, 1994: 172; Knoke and Burt, 1983).

For symmetrical ties like the research alliances in this study (the directions of the relationships are not specified) prominence can be operationalized with the measurable construct of "centrality" (Wasserman and Faust, 1994: 172; Knoke and Burt, 1983). In general terms, a central actor is defined as one involved with many ties (Wasserman and Faust, 1994). More specifically, the literature has distinguished several types of centrality (Freeman, 1979). For example degree centrality simply measures the number of partners with which a local firm is allied, closeness centrality focuses on the distance of an actor to all other actors, betweenness centrality implies that a central actor must be between many of the other actors and eigenvector centrality calculates an actor's centrality as its summed connections to other actors, weighted by their centralities (Wasserman and Faust, 1994).

In this study, we operationalize the prominence of an organization in the national research alliance network using Bonacich (1987) eigenvector centrality, a choice that is consistent with prior efforts in the alliance literature (Gulati and Gargiulo, 1999; Podolny, 1994; Mizruchi, 1993). Using this construct, the most central organizations are defined as "those linked to many organizations, which are in turn linked to several other organizations" (Gulati and Gargiulo, 1999). In simple terms, if a firm's net-

work contains many central actors its eigenvector centrality should also be high. If, however, a firm's network includes fewer and mainly peripheral actors, then its eigenvector centrality should be low.

A central position in the network can increase a firm's ability to form alliances via two mechanisms (Gulati and Gargiulo, 1999). Firstly, from the new venture's point of view, central organizations have better access to fine-grained information and knowledge about potential partners and collaborative opportunities through their larger "intelligence web" (Gulati, 1999; Powell et al., 1996).

Secondly, from the perspective of an international partner initiating an alliance, high centrality of the local actor signals a good reputation and trustworthiness, which makes it more attractive as a local partner (Gulati and Gargiulo, 1999). For the international alliance partner, a big concern is the predictability of the local partner's behavior. Faced with lack of prior experience with a particular domestic partner, the next logical step is to rely on the reputation of that firm, which is a direct consequence of that firms' prior relational behavior (Granovetter, 1985). Within a network, reputational considerations play an important role in a firm's potential for future ties, because these social affiliations serve as a source of legitimacy (Uzzi and Lancaster, 2003; Gulati and Gargiulo, 1999; Uzzi, 1996). The signaling properties of a firm's network centrality are particularly important for knowledge-based industries (Podolny, 1994) and for collaboration across national boundaries (Al-Laham and Amburgey, 2005). Reflecting the above, we suggest that the centrality of a firm in national research networks would: a) provide information and knowledge benefits and b) make the firm more visible and signal good reputation, thus raising the probability of internationalization via international research alliances.

Hypothesis 2b. The greater the centrality of a new venture within its domestic research network the greater its probability of internationalization via international research alliances.

4. Data and methods

4.1. The context

The data used in the study consists of the complete population of 853 German biotechnology firms in existence in 1995 or founded thereafter. Hampered by a hostile regulatory environment for genetic research throughout the 1980s and early 1990s and facing additional institutional constraints, the

German biotechnology industry was *de facto* non existent prior to the mid 1990s (Kaiser and Prange, 2004; Casper, 2000). Up to that time, only a few commercial biotech labs were in existence, most of which were side businesses of large pharmaceutical firms. However, in the mid 1990s, the German government introduced a series of new technology policies designed to orchestrate the development of innovative technologies and small business start-ups (Kaiser and Prange, 2004). Among those policies was the liberalization of genetic testing regulations in 1993 and the introduction of substantial technology promotion programs since 1995. The most successful of these programs are the so called "Bio-Regio" Competitions that created and promoted clusters of entrepreneurial firms by funding biotechnology promotion offices in 17 German regions (Wilson and Souitaris, 2002).

Additionally, many public grants, loans and subsidiary programs were created to finance the high-tech start-ups. To offer finance opportunities for young firms, the German Government also worked with the financial community to introduce measures designed to stimulate the provision of higher risk investment capital (Casper 2000, p. 893). As a result, in 1997 a new stock exchange, the "Neuer Markt" was created, that favored young start-ups by applying substantial lower listing requirements than those that exist for the main stock market. These and other institutional changes have led to a dramatic increase in the numbers of German biotech start-ups, most of which are located in bioregio-clusters around universities and public research institutes (Ernst & Young 2003).

4.2. The sample

Although the majority of firms (approximately 95%) were founded after 1995, our sample includes some firms from the pharmaceutical and chemical industries that have changed their business model and transformed themselves into biotechnology firms. We used four primary sources to compile the sample. The first were the daily registration and deregistration records of the German Commercial Register ("Bundeszentralregister") in Berlin; the second was the "Yearbooks of the German Biotechnology Industry", published annually by the German company Biocom AG. The third source was archival data coded from the monthly TRANSCRIPT newsmagazine that reports on the German biotech industry; and from German and European newsmagazines such as FT, FAZ or Handelsblatt. The final

source was the monthly records from the German Patent and Trademark Office in Munich, published by PATHOS GmbH (source for the assignment of patents). We identified 853 German independent firms (excluding subsidiaries, divisions and joint ventures) and we observed them from 1995 until 2004.

We constructed an event history for each company. Event histories are data structures that include information on the number, timing and sequence of the events that are being examined. Each firm's history began at the time of its incorporation or qualification to do business and ended at the time of an event (such as an alliance) or at the end of the month, whichever came first. The organization's second spell began on the following day and ended at the time of an event or the end of the month. This pattern continued until the firm exited (through failure or acquisition) or until the end of the observation period, in which case, spells were coded as "right censored." This procedure allowed time-varying covariates to be updated at monthly intervals. In those cases where only the month and year of an event could be determined, the day was set at the midpoint of the month to minimize timing errors.

4.3. Dependent variable

The dependent variable is the international alliance formation rate $\lambda(t)$. The rate is defined as

$$\lambda(t) = \lim[q(t, t+\Delta t)/\Delta t], \Delta t \rightarrow 0$$

where q is the discrete probability of the firm entering into a research alliance with an international partner between t and $(t+\Delta t)$, conditional on the history of the process up to time t. This rate summarizes the information on the intervals of time between successive events, with higher values of the rate corresponding to shorter times between events and vice versa. Factors increasing the rate are therefore increasing the speed of the firm’s internationalization and vice versa. For the period under observation (1995-2004) 251 international research alliances by 81 firms have been recorded. Figure 2 depicts the organizational type of the international research alliance partners of German biotech firms.

Figure 2 about here

4.4. Definition of the cluster

The literature indicates that most methods for determining clusters are not precise (Cooper and

Folta, 2000). In the US, most researchers have defined clusters according to state boundaries (Krugman, 1991; Shaver and Flyer, 2000). Others have chosen the Metropolitan Statistical Area (MSA) (Coombs et al. 2006; DeCarolis and Deeds, 1999; Zucker et al., 1998) to link firms more explicitly to the economic activity in their region and to consider situations where there may be multiple clusters in a single state (e.g., San Francisco, Los Angeles, and San Diego in biotechnology).

In Germany there is no MSA equivalent and therefore we opted for the post code location. The German post code uses a five-digit system, where the first digit reflects the city, the second digit the suburbs within the city, and the last three digits the street level. After talking to peers, German biotechnology experts and an official representative of the German post specializing on geo-distance measures, we found the two-digit code to be a good compromise between the city and the street level. German biotech clusters are formed in smaller geographical areas than in the US - such as a neighbourhood or suburb - with firms locating very close to each other. This reflects to some extent the generally higher population density in Europe than in the US. The German two-digit post code covers a smaller area than an MSA, but it was the most appropriate clustering criterion for the particular context.

Our clustering system produced 73 biotech clusters in Germany. The total number of firms in a cluster was the number of biotechnology firms (organizational type I), universities and research institutions (type II), laboratory equipment and input suppliers (type III), biochemical and pharmaceutical firms (type IV) and consulting firms (type V) located in the same two-digit post code area.

4.5 Independent variables

4.5.1. A cluster's "international alliance intensity": We counted all prior alliances at the cluster level established by any of the organizational types described above (Categories I-V) that involved at least one international partner. To calculate international alliance intensity, we weighted the total count of international alliances by the total number of organizations in the cluster to account for the size of the cluster.

4.5.2. A cluster's "simple density with public research institutions": This was the total number of public research institutions located in a cluster.

4.5.3. A cluster's "organizational diversity": We constructed a Herfindahl index according to the formula:

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

where s_i is the proportion of firms in the cluster from organizational type *i*, and *n* is the number of different organizational types (I-V). Thus the index describes the entropy of organizational types in the cluster, considering cluster size.

4.5.4. Prior local research alliances of biotech firms with public research institutions: To construct the measure we counted the number of research alliances a biotech firm had established with a public research institution located within its two-digit post code. The cumulative count measure was updated on the day that an alliance was formed.

4.5.5 Prior national research alliances of biotech firms: We counted the number of research alliances the cluster's biotech firm had established with German partners outside the same two-digit post code. This measure was updated on the day that an alliance was formed (as with local alliances with research institutions).

4.5.6 Centrality of a biotech firm within its national research network: The Bonacich's (1987) eigenvector index is a sophisticated and popular measure of a firm's centrality. It reflects the degree to which an actor's centrality is a function of the centrality of the actors to whom the actor is connected (c.f. Wassermann and Faust 1994: 209). Therefore, a biotech firm's centrality is a function of the number and the centrality of the firms with which it forms research alliances. In turn, the centrality of these partners is a function of the number and the centrality of their partners, and so on.

All national research and development alliances in effect during a quarter were used to construct the research network for that quarter. The UCINET program was used to construct the Bonacich (eigenvector) centrality score for each organization in the network. This indicator can formally be defined as:

$$s_t(a,B) = \sum_{\kappa=0}^{\infty} aB^{\kappa} R_t^{\kappa+1} \mathbf{1}.$$

In this expression, a is a scaling coefficient, B is a weighting parameter that can range from zero to the

absolute value of the inverse of the value of the maximum eigenvalue of the sociomatrix R_t, 1 is a column vector where each element has the value "1," and s_t is also a column vector where element $S_{i,t}$ denotes the centrality of biotech firm i. The B parameter is set equal to the reciprocal of the maximum eigenvalue.

4.6. Control variables

We included as controls nine variables at the firm level that are known or expected to affect the likelihood of internationalization but not included in our hypotheses.

4.6.1 Age of the firm was measured as the number of days since the founding of the firm.

4.6.2 Size of the firm was measured by the number of employees the firm reported.

4.6.3 Number of research domains: We used two control variables to account for the absorptive capacity of a firm (i.e. its ability to recognize the value of new knowledge from international partners, assimilate it, and apply it to commercial innovations) (Cohen and Levinthal 1990). The first of these controls was the number of research domains, indicating the breadth of the firm's knowledge base. We used self-reports compiled in the Yearbook of the German Biotechnology Industry to classify each firm, e.g. polymer protein coating, tissue engineering. A maximum of 13 research domains were reported by the firms. The number of research domains in which firms were active was a simple count. Although the variable is relatively stable there were fluctuations over time.

4.6.4 Sophistication of laboratories: A second indicator of absorptive capacity is the firm's technological sophistication. Following Casper (2000) we assumed that the sophistication of a biotech firm's technological knowledge is to a great part reflected in the technological sophistication and complexity of its laboratories. A total of eight laboratory types were used to classify biotech firms, according to the requirements of the German Ministry for Education and Research: chemical lab, chemical-biological lab, L1, L2 and L3-Lab, S1, S2 and S3-Lab. L3 and S3 laboratories adhere to the highest technological complexity and security standards. We therefore constructed a dummy variable (sophistication of laboratories) indicating whether or not the firm was utilizing a L3 or S3 laboratory.

4.6.5 Prior patents of the firm: We used the cumulative count of the firm's prior patents to control for its innovative productivity, which might add to its attractiveness as an international alliance

partner.

4.6.6 Private Placements of equity: To control for financial inflows, we used the cumulative count of the number of private equity investments the firm received. This variable was updated on the day that an investment was made.

4.6.7 Prior international alliances of the firm: A cumulative count of prior international alliances of the firm was included to control for the effect that prior international experience might have on the internationalization probability.

4.6.8 Cluster age: To measure cluster age we had to set a starting date for the existence of the biotech cluster. The founding of a biotech cluster corresponded to the time of the first founding of a biotech firm in the local two-digit post region. We measured the cluster age (in days) whenever an event under observation occurred by subtracting the starting time of the cluster from the time of the event.

4.6.9 Prior local research alliances of biotech firms with organizations other than public research institutions: We counted the number of research alliances a biotech firm established with any other organization except a public research institution located within its two-digit post code. The cumulative count variable was updated on the day that an alliance was formed.

4.7. Model

Since the occurrence of international alliances over time for a firm constitutes a series of repeated events, event history analysis is a very useful analytical technique. The event series was modeled as a stochastic point process (Amburgey 1986). The international alliance formation rate $\lambda(t)$ was specified as an exponential function of the independent variables and a set of parameters capturing the effects of the variables on the rate such that:

$$\lambda(t)=\exp(\beta X_t).$$

The use of an exponential baseline model, such as the one above, is common in event history analysis. Since we included two different functions of time (age of the firm and age of the cluster) as explicitly measured covariates, we did not use a Weibull specification to add a second model parameter for monotonic time dependence. Parameters were estimated using maximum likelihood with the

STATA (9.0) program. The estimation procedure clustered observations by firm to reduce the impact of unobserved firm-specific effects (White 1982). The significance levels of the parameters were evaluated by examination of t-ratios, whereas the goodness-of-fit of the different models was evaluated by examination of likelihood ratio statistics. The likelihood ratio statistic describes the improvement in fit between hierarchically nested models and follows a chi-squared distribution with degrees of freedom that are equal to the difference in the number of parameters of the two models. We used two models to evaluate our hypotheses. The first model includes only control variables and constitutes a baseline model. The second and full model adds the cluster, alliance and network variables. This model was used to evaluate our two sets of hypotheses.

5. Results

Table 1 provides means and standard deviations for the variables in our models as well as a correlation matrix. It indicates moderate intercorrelations among the independent variables. Given the large number of observations in the data, multicollinearity was not likely to be a problem. However, to test explicitly for multicollinearity we computed the eigenvalues of the variance-covariance matrix of the estimates. The ratio of the largest to the smallest eigenvalue indicates the numerical difficulty in approximating the likelihood surface. The test indicated no numerical difficulties despite the correlations between some of the variables.

-Table 1 About Here-

Table 2 presents the results of our event history analysis. Likelihood ratio tests comparing all of the models to a constant rate (random process) model are included at the bottom of each column. Model 1 provides parameter estimates only for the control variables. The likelihood ratio chi-squared test indicated that the baseline model was a significant improvement over a random, constant rate model. The parameter estimates in Model 1 indicated that four of the control variables had a significant impact on the rate at which firms internationalize via research alliances: firm size, breadth of research domains, prior international alliance (indicating that prior international experience accelerates the rate of interna-

tionalization) and the number of local alliances with non-public research institutions.

Model 2 added parameter estimates for the cluster-related variables and the nationwide ties. The results show that only two of the measures for the local cluster - international alliance intensity, and prior local alliances with research institutions - were positive and significant. Simple density with public research institutions and organizational diversity of the cluster were not significant. Therefore Hypotheses 1a and 1d were confirmed. In contrast Hypotheses 1b and 1c were not confirmed. In addition, our measure for prior national research alliances proved significant and positive, providing support for Hypothesis 2a. Finally, our measure of eigenvector centrality of a firm within the national research network was significant and positive, supporting Hypothesis 2b. Model 2 was not only a significant improvement over a constant rate model, a likelihood ratio test comparing Model 2 with Model 1 indicated that it provided a significantly better fit with the data.

-Table 2 about Here-

6. Discussion

This work identified factors acting as prerequisites or as enabling conditions for new ventures entering into international research alliances, thereby addressing the internationalization of new ventures in a broader sense. Our work was inspired by the lack of empirical research on the role of local and national networks as drivers of internationalization of new ventures via research alliances. We therefore explore an important, yet under-researched area and contribute to the literature on international entrepreneurship, specifically differentiating between the effects of local and national research ties. Moreover, our investigation of the effect of cluster location on the formation of international research alliances contributes to the alliance literature (Coombs et al., 2006). Also, by differentiating specifically between the effects of local and national network ties we extend the contingency perspective in organizational networks (Gulati, 2003). In addition, we add to the network literature by predicting further international network development (in the form of research alliances) based on prior network ties (Hoang and Antoncic, 2003). Methodologically, the paper is original, because it is a longitudinal study of the complete population of the emerging German biotechnology industry since its inception.

The empirical findings partially confirmed our local embeddeddness arguments (two out of the four hypotheses were supported). Firstly, we found that German biotech firms benefit from the presence of internationally connected organizations in their local cluster. There is a very strong statistical relationship between prior international alliances within the cluster and the internationalization of biotech firms via research alliances. We believe that this finding provides implicit support to the literature on knowledge spillovers (Zucker et al., 1998; Audretsch and Feldman, 1996). By virtue of knowledge spillovers from internationally linked organizations young biotechnology firms are able to get information on potential international partners. Furthermore, by observing successful international alliances within the local cluster, biotech firms might learn about and subsequently emulate the technological capabilities that foreign firms hope to acquire when entering the German market.

Interestingly, the simple density with public research institutions and the organizational diversity of the cluster did not prove to be significant determinants of internationalization via research alliances. Building on earlier literature (Gittelman and Kogut, 2003; George et al. 2002) we expected a location in a cluster dense with public research institutions to raise the probability of internationalization via research alliances. Moreover, we expected the synergistic interplay of a variety of organizations within a cluster (Lowe and Gertler, 2005; Prevezer, 1998; Shohet, 1998) to create a specific localized capability profile and attract international firms into the region. There are several plausible explanations why our data did not support these hypotheses. First, it might be that the only benefits that firms can gain from being located within a research-active and organizationally diverse cluster compared to firms outside the cluster - are cost advantages (Maarten de Vet and Scott 1992). Although some cluster characteristics might be important for a firm's initial founding decision, operational costs or even innovation rate, they might not speed up internationalization efforts. Furthermore, perhaps the short period since the inception of the German biotech industry (it basically started in 1995 and gained a phenomenal growth momentum after 2000) did not allow sufficient time for spillovers of technical knowledge from the local research institutions or for the development of that idiosyncratic, valuable "localized capability profile" reflected in the combined expertise of a variety of local actors.

Moving from general cluster characteristics to firm characteristics within the cluster, we found

that the prior research alliances of cluster firms with local research institutions, were a significant driver of further international research alliances. This is a very interesting finding, especially combined with the non-significance of the simple density with research institutions of the cluster as a whole. This suggests that proximity to research institutions in a local cluster is not the same as actual collaboration with them. Our results are in line with Zucker et al.'s. (1998) argument that knowledge (at least technical knowledge as in our case) does not transfer via informal spillovers such as local social and trade meetings, but actually through direct collaboration among scientists.

Our second set of hypotheses discussed the effect of national networks on the probability of internationalization via research alliances. We found that the firm's number of prior national ties significantly increases its probability of entering an international alliance. Our main explanation for this finding involves experiential learning and its effects on entry into alliances. We expect that firms that accumulate prior experience with national alliances to develop generalized "alliance-capabilities" (Khanna et al. 1998; Gulati 1995a), such as the ability to select partners and to manage the learning and joint development within the alliance.

We have made a distinction between the effects of local research alliances in the cluster and of national research alliances, despite suggesting that they both have a role in raising the probability of international alliances. We believe that the underlying explanation of their effects is slightly different in terms of the balance of benefits from technical knowledge spillovers and from alliance capabilities: alliances with local research institutes offer primarily technical knowledge which raises the firm's profile as a potential local partner and secondarily help to build up alliance capability. Instead the main benefits of national alliances are experience and capability in managing collaboration with geographically remote partners and secondarily technical knowledge.

We also found that a firm's centrality within its national research network affects its probability of internationalization via research alliances. We used an empirical measure of the firm's network centrality (the eigenvector centrality) which not only reflects its own position, but also the position of the partners with which the firm cooperates. Research has shown that firms with a high centrality within their network have greater access to and control over resources such as knowledge (Podolny 1994,

2001). Even more importantly, central firms are perceived as having better national reputation a key characteristic for being selected as an international alliance partner.

7. Limitations

Our study has the following limitations:

Other cluster-related variables and measures could affect internationalization via research alliances. Future experimentation with other potential measures might capture other aspects of the cluster's benefits. For example, a cluster's "technological munificence" is a sophisticated index measure used by Coombs et al. (2006) capturing grant numbers and value, number of medical schools and science departments and the size of the cluster in terms of the proportion of the whole industry that it represents. Our "simple density with research institutions", "international alliance intensity" and "organizational diversity" measures were based on data availability and were simple but explicit and factual. Moreover, our decision on the size of a cluster could be questioned and it affects our models. Using the first-digit (city) or the three-digit (street) post code would change the number of clusters. However, after consultation with colleagues, industry and postal experts we were convinced that the two-digit code was the most appropriate measure to capture the German biotech cluster.

The generalizability of our results could also be challenged as the sample represents a single industry (biotech) in one country (Germany). However, there is prior evidence that research results from the biotechnology industry are generalizable to other high technology industries such as semiconductors (Almeida, 1996; Coombs et al. 2006).

8. Summary and implications

Our research addressed the question of whether embeddedness of firms in knowledge intensive regional clusters and national research alliance networks affect the probability of internationalization via research alliances. Our results provide clear support for the benefits of national cooperation before entering into international alliances. Gaining experience at the national level allows firms to develop valuable capabilities for international research alliances. We found mixed support for the influence of

cluster embeddedness. Some characteristics of clusters are beneficial (the cluster's international experience and firms' collaborative links with public research institutions) while others do not have a significant effect (density with research institutions and organizational diversity of the cluster).

Overall our results extend recent work on foreign firms' motivations to ally with local biotechnology partners (Coombs et al., 2005). We generally concur with their conclusion that foreign firms are investing to access regional benefits (i.e. clusters matter) and we elaborate on a number of cluster characteristics that are beneficial. More importantly we propose that foreign firms are also investing to access country-specific benefits. The latter are not linked to geography (as in the case of cluster-investing) but to the position of domestic firms within the national network structure (network size and firm's centrality within the network), especially in cases of "small world" structures like Germany.

We also believe that our results shed new light both on the importance of local knowledge spillovers in an international context and on the sources of knowledge spillovers. We confirm that local clusters foster the internationalization of new ventures by increasing their awareness of international opportunities, and by offering an arena to learn from the experience of internationally connected firms.

We see several implications of our research for entrepreneurs managing new ventures seeking to internationalize. First, new ventures have to develop links at the national level. Such national cooperations are a prerequisite for international alliances not only because they offer access to network economies and knowledge spillovers, but also because they offer an arena in which the firm can develop cooperative capabilities, a competence that is fundamental for international linkages (Erramilli 1991). It would therefore be beneficial for them to network on a national level first before they embark on international alliances. Second, the centrality of the firm within the national network seems to be of high importance not only in building these capabilities, but also in attracting international partners. Therefore, new ventures should assume a central role in the national network early on, for instance by participating in research or joint development projects with high status biochemical or pharmaceutical firms. Third, the local cluster only partially contributes to the probability of internationalization. Our results show that it is not so much the publicly available infrastructure within clusters, but rather the active involvement in alliances and networks that fosters a firm's early internationalization.

9. Future research

The principal aim of this work has been to gain a fuller understanding of the determinants of international expansion of young and entrepreneurial firms. We see several areas for future research. As has been suggested by Jones and Coviello (2005, p. 299) one important topic for future research is the extent to which networks and firms' internationalization strategy are self-reinforcing - that is, how internationalization influences network structure and vice versa. While this research has focused on the latter aspect, we see potential merits in examining the structural consequences of the international experience of network members. In this vein, potential future questions could be: do firms with international experience increase their centrality within their network over time? Is a firm's network centrality influenced by the international experience of other firms within its network component (subnetwork)? Are there benefits (network effects) from the international experience of central firms for the growth and innovativeness of peripheral firms? More generally, how does the interplay of internationally exposed firms and nationally linked firms shape the structural evolution of the network?

At the firm level we see a potential avenue for research in measuring the interaction effects of cluster and network embeddedness and the absorptive capacity of a firm. The literature on organizational learning suggests that firms vary in their absorptive capacity, their ability to recognize and access external knowledge and to exploit internal knowledge. Since absorptive capacity will contribute to accessing knowledge flows within the cluster or network, it can be assumed that absorptive capacity will have a moderating effect on the relationships between flows of knowledge and firms' internationalization. So far there has not been any systematic attempt to measure the moderating effects of absorptive capacity.

Another avenue is to extend the research to include the innovative and/or commercial outcomes of international alliances by biotechnology firms. The resource- and knowledge-based theories of the firm are, at their foundation, concerned with competitive advantage and the generation of economic rents. Extending our research to include measures of, for example, success in generating patents or commercial viable products would offer additional important insights.

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Figure 1: The study's conceptual model

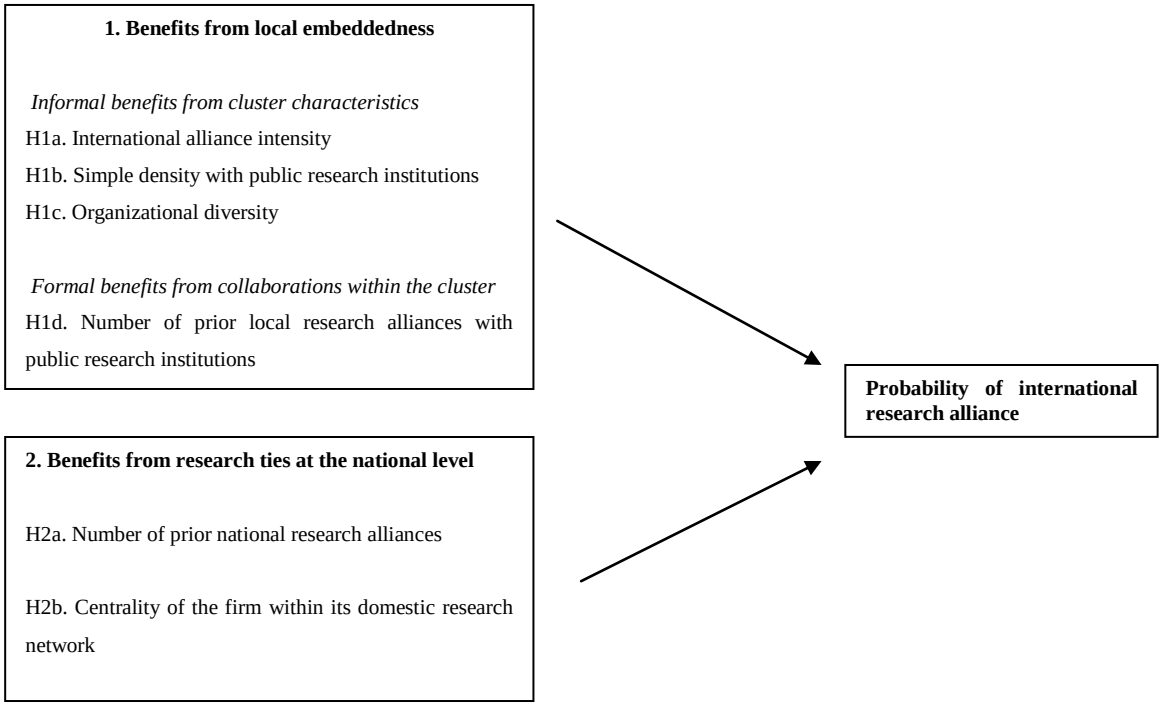

Figure 2: The organizational types of the international research alliance partners of German biotech firms

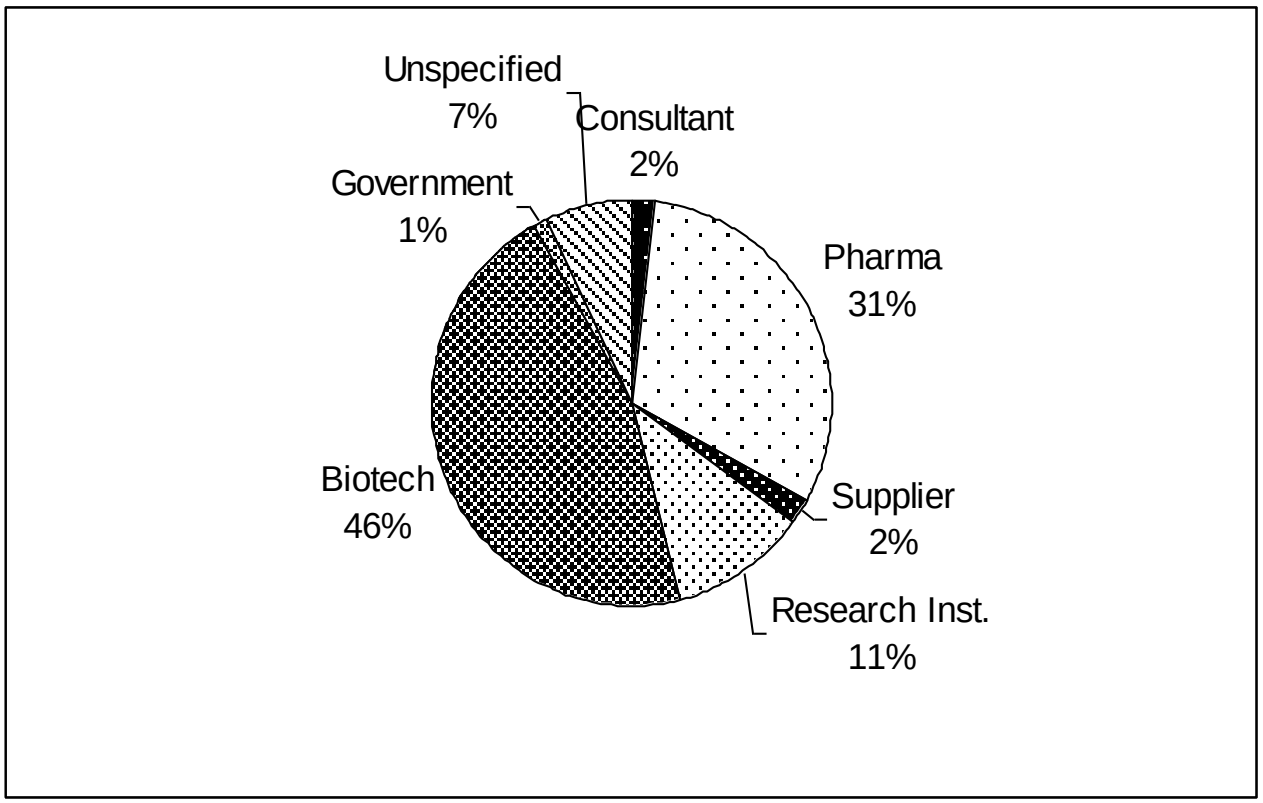

TABLE 1: Descriptive Statistics

Variables	Mean	S.D.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Firm age	1691	1766	1.00														
2. Firm size	35.86	84.85	.121*	1.00													
3. Research domains	1.76	3.012	.105*	.098*	1.00												
4. Sophistication of labs	.092	.289	.518*	-.099*	.022	1.00											
5. Prior patents	15.53	57.014	.717*	-.078*	.006	.729*	1.00										
6. Private placements of equity	.0086	.092	.032*	.191*	.005	-.029*	-.020	1.00									
7. Prior international alliances of the firm	.50	2.02	.125*	.695*	.032*	-.063*	-.042*	.241*	1.00								
8. Cluster age	3731	2391	.188*	.196*	.036*	.008	.003	.041*	.160*	1.00							
9. Prior local research alliances with non-research institutions	.3931	1.404	-.025	.288*	.080*	-.089*	-.055*	.131*	.451*	.065*	1.00						
10. Cluster's international alliance intensity	.00019	.0023	-.017	.134	.022	-.026	-.013	-.007	.020	.049*	.073*	1.00					
11. Cluster's simple density with public research institutions	15.51	10.36	.010	-.976*	.062*	.150*	.019	-.021	-.083*	.387*	.007	-.018	1.00				
12. Cluster's organizational diversity	.33	.11	.344*	-.092*	.0006	.353*	.559*	-.015	-.054*	-.299*	-.034*	-.015	-.269*	1.00			
13. Prior local research alliances with public research institutes	.086	.47	-.051*	.185*	-.020	-.058*	-.029*	.060*	.139*	.154*	.331*	.083*	.098*	-.081*	1.00		
14. Prior national research alliances	.49	1.48	.067*	.597*	.112*	-.104*	-.060*	.181*	.807*	.160*	.61*	.094*	-.008	-.046*	.199*	1.00	
15. Centrality within national research network	1.36	9.56	-.040*	.179*	-.035*	-.045*	-.024	.036*	.162*	.153*	.18*	.011	.098*	-.071*	.609*	.212*	1.00

*****correlations significant at $p < .05$ Based on 5570 spells

TABLE 2: The effects of network embeddedness on the rate of international research-alliance formation

Variables	Model 1	Model 2
Firm age (Days)	-.0000349	.0000377
	(.0001167)	(.000112)
Firm size (Number of Employees)	.001872●	.0015247●
	(.0006364)	(.0007044)
Number of research domains (Count)	.0641038●	.062172●
	(.0268776)	(.0281372)
Sophistication of laboratories (dummy)	.4356385	.7219814
	(.7880834)	(.7505415)
Prior patents (Count)	-.002029	-.0058919
	(.0070163)	(.0096213)
Private placements of equity (Count)	-.8704997	-.6762406
	(.6983868)	(.767076)
Prior international alliances of the firm (Count)	.2130607●	.069807
	(.0379726)	(.0816824)
Cluster age (Days)	.0001042	.0000526
	(.0000583)	(.0000662)
Prior local research alliances with non-research institutions (Count)	.1924661●	.0445018
	(.045745)	(.0517176)
Cluster's international alliance intensity (Ratio)		40.30062●
		(12.83026)
Cluster's simple density with public research institutions (Count of public research institutions)		-.0188463
		(.0144392)
Cluster's organizational diversity (Herfindahl index)		-2.605532
		(1.831978)
Prior local research alliances with public research institutes (Count)		.2677357●
		(.1401074)
Prior national research alliances (Count)		.2998549●
		(.1061936)
Centrality within national research network (index score)		.0209501●
		(.0055773)
No. of Observations	5570	5570
No. of International Research Alliances	251	251
Chi-squared	354.08	1088.25
Degrees of Freedom	9	15
P Value	P<.001	p<.001

● **Significant at p<.005**