

Working Paper

No. 2003.12

Jesper Norus

**Exploring Entrepreneurial Network
Relationships – Forms and facades in
formation of the biotechnology firms**

**INSTITUT FOR ORGANISATION OG ARBEJDS SOCIOLOGI
Handelshøjskolen i København
Solbjerg Plads 3
2000 Frederiksberg
Tlf: 38 15 28 15 Fax: 38 15 28 28**

Exploring Entrepreneurial Network Relationships – Forms and facades in formation of the biotechnology firms¹

By Jesper Norus
Department of Organization and Industrial Sociology
Copenhagen Business School
Solbjerg Plads 3
DK 2000 Frederiksberg
Denmark
phone +45 38152831
Fax +45 38152815

jn.ioa@cbs.dk

Full paper accepted for presentation at the NNF 2003 conference to be held in Rejkjavik, Iceland
August 14-16
Track: "Entrepreneurship in different organizational and societal contexts"

¹ Keywords: Network Strategies, new organizational forms, biotechnology, network conditions.

Abstract

In the recent years the successful collaborative arrangements and relationships between university, industry and public institutions have become a mantra in transforming new scientific knowledge into new innovations and business ventures. The fit between these very different actor groups has been treated as a contingent factor. However only little attention have been giving to a specific focus on the strategies that new business ventures have obtained to establish the fit between small firms, university research, and public policies such as regulatory policies and R&D policies. The emergence of the new biotechnologies and these techniques predominately coming from the university sector make the new biotechnology organizations an interesting object for studying these relationships both on a regional and a national level.

From the perspective of the small biotechnology firms (SBFs) the paper explores four different strategies for dealing with network relations; the research oriented strategy, the incubator strategy, the industrial partnering strategy, and the policy-oriented strategy. The research-oriented strategy is narrowly focusing on how a biotechnology firm transforms their scientific results into promising technologies, services or products. The incubator strategy is concerned with localization and how to come about specific types of managerial problem in the initial stage of forming a business venture. The industrial partnering strategy concerns how to overcome the problem of bringing the technologies from an experimental stage at a research lab to be able handle industrial processes and full-scale production. Last but not least the policy oriented strategy focus on problem of having products approved by the public authorities.

Theoretically the article draws upon network theories and a dynamic view of network relations. That is done in order to capture the nature of the relationships between different types of actors, but also in order to emphasize the informal nature of some of these relationships.

The article has a dual purpose; 1) From a corporate point of view to emphasize multiple conditions for developing and forming interorganizational relationships, 2) From a research perspective to point to the diversity and heterogeneity of these relations and thereby emphasizes the evolutionary nature of these relations and their relatedness to the overall strategies obtained by the biotechnology entrepreneurs.

The paper is structured so it will start out by stating its methodological foundations. Thereafter the theoretical positioning of the network approach will seek to argue that we have multiple network relationships are at play. Not only do these networks differ but also the institutional and organizational origins are to be touched upon to come to understand the nature of the biotechnology environment and the actors involved. The positioning of the SBFs as the focal point of the analysis leads to a discussion on entrepreneurial business strategies in biotechnology industry and how these business strategies in a very distinct mode is correlated with interorganizational relationships. The empirical evidence will be fleshed out in four cases representing each of the four suggested strategies. The conclusion discusses three implications of network partnering analysis. First, it discusses the theoretical contributions on the diversity, heterogeneity between the four partnering strategies. Second, it will point to future directions in the research. Third, the conclusion will point to the managerial challenges that can be foreseen.

Data collection and research method

The paper is the result of a longitudinal case study based on qualitative data on the co-evolution of strategies and networks in the biotechnological industry in the US and Denmark. From a total population of 32 small biotechnology firms, the study identified three different types of network-based strategies undertaken by the entrepreneurs in the biotechnological industry: the project strategy, the incremental strategy and the vertical integration strategy. After these first initial results five of the 32 firms have been investigated over a period of 8 years in order to study how networks evolved over time and how network co-evolve the development of the firm's business strategies.

In total the empirical data consists 67 interviews with people from the biotechnological community in the San Francisco Bay Area, San Diego, Boston, New York City, Chicago, Research Triangle Park, North Carolina and Copenhagen, Denmark. From the 32 SBFs in the population five SBFs was selected for further longitudinal case studies.

Table 1: Geographic Distribution of Interviews

Boston	7
Chicago	10
New York City	3
Research Triangle Park, NC	9
San Diego	4
San Francisco Bay Area	17
Copenhagen, Denmark	17

Table 2: Institutional Background of Informants

Small Biotechnological Firms	52
Research Parks	3
Universities (Licensing Offices)	7
Public and regulatory bodies	6
Venture capital firms	6

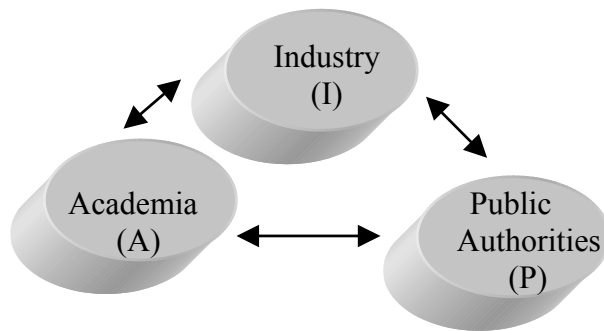
The interviews were conducted in three different periods. The first series of interviews were held over a period of 8 months in 1993-94. The second phase took place in late 1997 where only small biotechnological companies were visited. The third phase took place by the end of 2001 where updating of the companies strategies was done through phone interviews in five SBFs. Looking closely to table 1 and table 2 the numbers of interviews exceeds the actual total numbers of interviews since some of the informants belong to more than one category which is a methodological problem especially when analyzing the data.

Empirical data further consists of written material, such as company presentations, annual reports, and corporate prospectuses. Moreover my data consists of Federal and State R&D Programs in biotechnology, and reviews of industrial related journals on biotechnology, such as all volumes of Genetic Engineering News from the 1970'ies to 1994.

Although the five SBFs have been selected due to their specific strategy it is interesting that they over the years have dealt very differently with respect to the establishment of relationships to public institutions and their relations to academia and industrial partners. Therefore in my view the four strategies are archetypes of how SBFs in a specific point in time overcome critical incidents to stay in business. Therefore one of the companies, Calgene, is selected to illustrate both the research-oriented strategy and the policy-oriented strategy. Insiders into biotechnology business for sure will wonder the absence of a venture capital strategy in the paper, especially if we take a close look at the global problems that small biotechnology companies are facing these years to attract financial resources. The short answer is that my five companies was selected at a point in time where they

had no problems attracting capital or deliberately avoided venture capital as their major financing source. The longer answer will be that in my view the difficulties that the biotechnology sector face is not only a consequence of the global slow down in the economy, but rather a problem that has to do with the globalization of the new biotechnologies. The industry therefore suffers from a dual problem the general economic situation and a restructuring of the technologies in question. A specific venture capital strategy and its direct impact on the formation of biotechnology firms therefore will imply an analysis of how the business strategies of SBFs have become globalised.

Figure 1: The nature of the Roles of actors in the proposed strategies



Research Oriented strategy: I - A - p

Industrial partnering Strategy: (I - I - I ..._n) - a - p

Incubator Strategy: I - A - I - P

Policy Oriented strategy: I - P - P - a

It is important to emphasize that the three types of actor groups have a much more complicated institutional background than is represented in figure 1. Therefore the most important actor groups will be fleshed out in a later section. Also the number of relationship to one actor group and the intensity of the relationships are varying and shifting over time which is indicated with small capital letters in the figure.

Theoretical positioning

The literature on biotechnology industry have primarily focused attention on the widespread formation of networks between the leading research institutions into the core biotechnology disciplines such as molecular biology and small and large biotechnology firms (Kenney, 1986; Kreiner & Schultz, 1993; Darby & Zucker, 1995; Robbins-Roth, 2000). The argument for the strong ties between academia and industry is based on three empirical assumptions. First, the basic scientific knowledge in biotechnology stems from universities or related institutions. Second, the vast majority of the new biotechnology ventures have strong antecedents in university settings. Third, small biotechnology firms have to get access to the new knowledge in their area to develop new biotechnology products and services.

Taking these assumptions for granted there are very good reasons why formations of networks have either been treated as the small biotechnology firms' possibility to stay competitive in relation to large and more resourceful firms or as a mode for small firms to enter into well-established markets

when only possessing few internal resources. Thereby networks have been treated, as a means of accomplishing goals that otherwise would have been impossible. I will not argue against this, but I will insist on the importance of investigating how particular networks are established and why the partners have engaged in these networks knowing that there are other partners out there. How do network partners meet and how has the collaboration developed over time? What characterizes a successful network relationship and what happens if the collaboration is cancelled and with what consequences? All these are interesting to cast light on and make the network perspective on collaborative arrangement between business much more vital. From my research in the biotechnology businesses, the SBFs have a less romantic view on searching for new partners.

Network Characteristics – Network Types and Network Dynamics

In management theories, the network perspective on organizations' establishment of collaborative relations to different actors such as people, institutions and firms has been transferred from sociological and anthropological research traditions. In the same way that socialization of human beings in a system of different types of personal networks of varying character and stability, it is taken for granted that firms also survive through different types of networks. The network studies vary from being predominately interested in the build up of interorganizational networks to focusing on how personal based relations e.g. bounded to professional groups are the major explanatory locus if one will understand the mechanism of how firms engage in external relations (Constant II, 1984; 1987; Kreiner & Schultz, 1993; Kristensen; 1995). These two streams of approaches introduce the problem of formal versus informal networks. The network metaphor captures, therefore, some important characteristics concerning the relations between the firms and its context such as customers, suppliers, knowledge institutions, financial investors, policy-making institutions etc.

Constant conceives of technologies as social arenas so-called communities of practice. Communities are viewed as carriers of the body of knowledge that encompass the technology in question (Constant II. 1984; 1987). Within communities of practice conflicts appear concerning the importance of different underlying techniques. The implication of this is that communities of practice consist of one or more technical representative that promote different design configurations that appear around a certain technology. One example that can illustrate this point is found in the case of Calgene, a SBF who developed a genetically modified tomato, Flavr Savr®. The emergence of the Flavr Savr® tomato gave birth to an intense debate among plant breeders on the technological concept of the Flavr Savr® tomato. One of the professional debates stemmed from a discussion among plant breeders from the agro-chemical firm Monsanto who noted that the result that Calgene reached through genetic engineering also could have been reached by the use of traditional plant breeding techniques. Hence, the introduction of the concept of communities of practice it is possible to capture a dynamic pattern in the way in which new technologies are developed and formed by gaining insight in the work, the methodologies, the patterns of communication and the career paths of the key researchers in the specific technologies in question. With respect to analysis of network relationships the concept of communities of practice allows the observer to dissolve the organizational boundaries between industry and academia and look at the informal relationships in the professional arena around a certain discipline or research area that foster the basic knowledge behind the technologies in question.

This is a very important issue when studying biotechnology firms due to the fact that biotechnology as a concept is consisting of a number of subsystems that are represented by the different

professional/technical approaches that the firms in question have chosen to follow in their methodologies of problem solving. Methodologies that are reflected in the networks the firms form and engage in and the relationships that the professional groups (communities of practice) participate in.

Another way of making the network perspective dynamic is to follow the networks the firms have developed over time. It is my hypothesis that that the majority of the networks start out as very loose contacts where both partners have the opportunity to try out the partnership before it is formalized is kept informal or stops. Other networks are by nature informal and temporary making them very difficult to depict and investigate. This is the case when a firm let a graduate student carry out her masters' thesis with the firm or if the firm lets talented students use their laboratories. One of the partners stops the collaboration and the project idea dies out. Another example is when an employee seeks new knowledge in his personal network that he afterwards forgets about because the information not used in the further development work, but was important knowledge that is transferred in a split-second were able to sort out ideas that otherwise would have been dead ends in the development work.

The relationships that are developed in the biotechnology industry tend to become more formalized. This became clear in the mid 1990'ies when the large chemical and pharmaceutical firms intensified their interest in new technologies by direct investment in SBFs. So from being predominately interesting in sponsoring basic research at the top universities the large firms started to buy up small promising biotechnology firms (Kenney, 1986). Despite this fact it is fruitful to maintain the opportunity to study the informal aspects of the relations and networks that the SBFs establish both with respect to industrial relations and their relations to acadmic settings.

In order to preserve this distinction between formal and informal it is therefore important to separate informal networks from the formalized network activities and seek to localize where in the organization the different networks appear and originate. At the same time it is important to find out how the communication flows and how communication is organized internally since the presented theories all point to the fact that the communication patterns determine the rate and direction of the established networks and the establishment of future network relations.

Figure 2: Network typology

	Internal	External
Formal	<p><i>Communication/flows of information</i></p> <ul style="list-style-type: none"> - Nature of hierarchy - Subsidiary – headquarter - Unit - Group - Superior – subordinate 	<p><i>Formalized contracts</i></p> <ul style="list-style-type: none"> - Strategic alliances - Joint Ventures - Outsourcing arrangements - Licensing agreements
Informal	<p><i>Personal based</i></p> <ul style="list-style-type: none"> - Sub-unit - division - Sub-unit – sub-group - Person to person 	<p><i>Trust based</i></p> <ul style="list-style-type: none"> - R&D collaboration - Internal jobmarkets - Person to person - Communities of practice

Figure 2 is a network typology that classifies networks and localizes them according to their organizational and institutional origin. The bold italicized headings in each of the columns indicate the overall trait or characteristics of the network relationships.

The typology is important for several reasons: First, the typology can be used to investigate how networks evolve over time. This is important in order to explain how the formalization of distinct types of networks happens over time and if distinct types of networks can be categorized to specific activities of strategic importance. Second, the typology can be used to analyze how networks are formed between different types of professions. For example, whether networks that are established by the management have a tendency to be more formal than networks that are established by the firm's researchers. In other words, the network activities have to be followed by a question on how these networks have evolved how come these networks and taken a specific form and character. Also one has to question whether all networks have strategic character or whether strategic networks have a specific form, character and organizational origin.

In the methodological sense it is important keep the distinction as relative pure forms to be able to investigate the origin of these network relations and see how they are created and how they develop over time. The strength of the figure is that it on the one hand seeks to classify different forms and types of networks, and at the same time also reveals the differences. This makes it possible to illustrate that there might be a dynamic movement in-between the different types of networks. Looking at the left side of table it is important to emphasize that the ability to form networks is limited by the internal organization and the way that the internal communication is organized. The reason the internal networks have been included is due to the widespread idea in organizational sociology that the more hierarchical and formalized the procedures are structured in an organization the more difficulty the members of the organizations will have in developing intraorganizational networks on their own. Moreover, a strict hierarchical structure will make it difficult for the individuals to mobilize resources through their personal network, for example in a community of practice, and there would also be limited possibilities to establish new personal networks. In both situations it will be impossible for the organization to utilize such types of networks experiences or "free resources" in the development of the company; it will also restrict the firm's employees from developing a personal network because they do not have any knowledge to exchange in the networks. The figure lists four forms formal and external network activities. Those networks are typically characterized as being contractual by nature. First, strategic alliances where a biotechnology firm receives revenues or payment to develop a specific product or project for a larger firm. Second, joint ventures where two or more firms develop a subsidiary firm has been one of the major forms of network activities that have appeared in the biotechnology industry. Joint venturing has also been one of collaborative arrangements where universities have been able to profit from their investments in basic research activities by engaging in setting up new businesses. Third, outsourcing arrangements is another formalized network activity that is widespread among the SBFs. The firms outsource activities for which they either do not have the competencies or the interest in taking care of themselves. It can be the production of cabinets for special devices or special components or activities such as production, marketing and distribution. Fourth, licensing agreements that imply that the small biotechnology firm leaves the production rights and the distribution of a product in return for a royalty fee. However the most common licensing agreement is when a firm or an institution patents a technique that they license out to partnering companies.

Both the informal and external networks are predominantly connected with research and development activities. These networks are most often formed within communities of practice and are guided by trust-based relations. They are also characterized as personal, implying that these networks, from the perspective of the organization, are not directly accessible but are, for instance, formed between former classmates or key personal from prior jobs. The personal relations or communities of practice also function as internal job markets. It is through these information channels that job opportunities are exchanged, which is of crucial importance for individuals that are employed in organizations that develop new technologies due to the insecurity concerning the viability of the technology in question. The insecurity of the technologies forces the employees to engage in communities of practice to have a platform to get a new job if the firm goes down. The risk to be excluded from the network combined with importance to belong to such a network diminishes the tendency to behave opportunistic. If excluded, an employee is relegated from having access to useful knowledge in his/her present job and will not get any of the attractive job opportunities that are exchanged within the technology of practice.

The Nature of the Environment

The biotechnology firms signal attractiveness by revealing both their formal and informal partnerships and networks with research institutions, universities, venture capital groups, pharmaceutical firms and other related businesses. The point here is that network formation is an essential activity for survival with much wider impact than just being a means of mobilizing knowledge and financial resources. It is never-ending stories since it is crucial to have access the most prestigious networks to legitimize the firm's present activities to further mobilize resources for the future activities. Hence the networks are to be conceived as cautious strategic choices that have to be made at different stages during the corporate life cycle.

Introducing the actors in the field of biotechnology

Although this articles overall aim is to have a closer look on the relations between entrepreneurs, academia and public and regulatory bodies it is very hard to neglect that other types of important actors intervene in this power triangle and play important roles as intermediate actors. Therefore these other types of actors are included in the overall description of the biotechnology community, but apart from the technology parks both the role of the venture capital and the pharmaceutical firms will be almost absent from the analysis in the cases presented.

In the field of biotechnology, six major actors and actor groups have been playing a dominating role in forming the new industry.

1. Small biotechnology firms that apply new biotechnological techniques to develop commercial products, projects, and services
2. Universities with strong research capabilities in new biotechnologies
3. Research or technology parks that function as incubators for small biotechnology firms
4. Public and regulatory bodies that have implemented biotechnology R&D programs in order to promote the biotechnology industry as well as institutions that have regulated the biotechnology industry by initiating product approval procedures and procedures for

environmental protection

5. Venture capital firms that have financed the start up of many biotechnology firms
6. Pharmaceutical firms that have bought up small biotechnology firms and engaged in licensing agreements and product development contracts, and thereby made sure that the venture capitalists can exit biotechnology firms/projects even before the small firms had products ready for the market.

Figure 3. The interactive nature of the biotechnology community

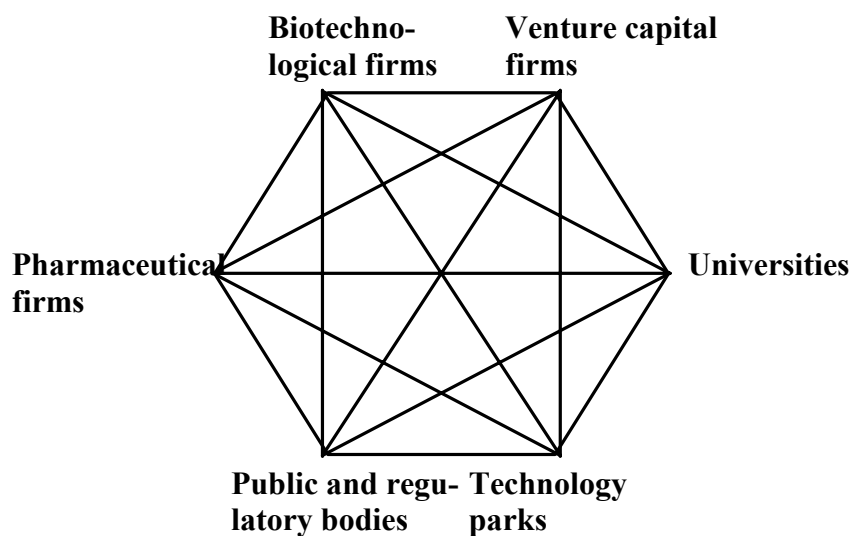


Figure 3 shows the interaction that takes place among small biotechnology firms in relation to the formation of network to key actors. However, in the figure all actors appear to be equal at all times which is not the case. Instead I think it is fruitful think of the six types of actors as necessary partners whith that relationships are to be formed over time. The argument is that these networks must be formed along with the development of the company. From the perspective of the individual firm, network formation can therefore be seen as a crucial co-evolving processes.

Entrepreneurial Strategies in biotechnology

The biotechnological industry has been formed and developed predominantly by small biotechnological firms with very strong roots and antecedents in the scientific environments (Powell, 1994; 1996; 1998; McKelvey, 1996; Kenney, 1986, Robbins-Roth, 1999; Norus, 2002). Although they have been able to develop quite sophisticated technological projects and products, the small biotechnological firms (SBFs) only have a few employees. These technological projects are developed through a wide range of collaborative arrangements, such as informal networks (research collaboration, resource sharing etc.) and formalized networks (joint ventures, licensing agreements and strategic alliances) with a variety of partners (venture capital firms, pharmaceutical and chemical firms, public and regulatory bodies, other small biotechnology firms, universities and research parks). This means that a variety of different networks arrangements are to be regarded as

means of survival in a new technological field where we would expect that only large multinational companies with large financial and human resources have the competencies and capabilities to direct and control the evolution of the technology in question.

Certain studies of biotechnology firms have applied a population ecology approach. However, these studies often fail to come to grips with central aspects of the industry in that they focus narrowly on the survival rate as the overall criterion of success (Barley; et.al, 1992; Orsinigo, 1989). The strategic decision-making in small biotechnology firms has not been given much attention. One criterion of success, and a distinct strategy, is that certain biotechnology firms continuously engage in selling off projects, and even entire companies, with the purpose of starting all over again. In this way, different firms under new corporate names continue the real assets, the R&D projects. Other companies live from selling commercial projects to large pharmaceutical firms. Therefore, a common characteristic of both the study of Barley et al. (1992) and that of Orsinigo (1989) is that they are incapable of capturing important characteristics about individual aspirations and strategic decisions in the new industry.

Orsinigo (1989) realizes that the knowledge of small firms is idiosyncratic and invisible in that the skills and competencies are embedded in the minds of key personnel rather than part of a visible product portfolio. However, this does not affect his overall conclusions on failure and success. What he describes resembles a death struggle in which the only way to heaven is to persuade venture capital firms to invest in the company or to go public in order for the firm to survive as an independent jurisdictional unit. If we take this analogy, the behavior of large pharmaceutical firms is to be compared with euthanasia. Such an explanation implies that entrepreneurs that have made fortunes are perceived as losing gamblers. Nothing could be farther from the truth and later on we will meet some of them - alive and well.

The problem is that entrepreneurs often have neither the aspirations nor the resources to develop, manufacture, market and distribute new biotechnology products. Their major interest is in developing the science and the technology and they sell promising R&D projects in order to create space for the development of their biotechnological competencies. A population ecology approach would tend to conclude that small biotechnology firms have had no impact on the development of the new biotechnology industry. Alternatively, such an approach would lead to the erroneous conclusion that new biotechnological techniques have no commercial interest since the developers, the small firms, have failed to market any new products. Instead companies that aspire to become vertically integrated do not have the necessary resources and must therefore engage in strategic alliances, and licensing agreements or they will eventually be bought up.

It is beyond doubt that the majority of small biotechnology firms are established with the ambition of expanding activities into a company that can develop, produce and market new biotechnology based products. Therefore it is not surprising that Peter Daly, in his book from 1985 on the industry, *The Biotechnology Business*, is preoccupied with business strategies based on different aspects of how small biotechnology firms have aimed at being vertically integrated companies. At that time, biotechnology had had its first boom on the stock market, and the firms in question therefore had sufficient financial resources to reach the goal. When investors and entrepreneurs realized the problems of scaling up the processes from an experimental stage to have cost effective full-scale production plants, the vertical ambition came to an end. Small biotechnology firms were needed to

develop mediating strategies with explicit exit strategies that were adaptable to the turbulent environment and flexible to the changes among the dominating actors in the biotechnology industry.

For analytical reasons it is important to distinguish between different types of biotechnology firms and different types of strategies that have developed over time for fulfilling the aspirations of the individual entrepreneurial firm. Therefore, it is fruitful to think of the biotechnology firm as a portfolio of related development projects of different chronological order. The project analogy is in accordance with the strategies pursued by the biotechnology firms in my population.

Because of the different character and combination of the collaborative arrangements undertaken by the SBFs it would be a flaw to search for an ideal strategy obtained by small biotechnological firms. A single best strategy in this area does not exist. Instead the search for best strategy has to be determined by the technological approach of the company, the aspirations of the entrepreneurs, and their modes of doing business through the organization and establishment of external networks. Three types of strategies undertaken by the SBFs will be outlined: the project strategy; the incremental strategy; and the vertical integration strategy. These three strategies have been identified through a qualitative study of the biotechnological industry in US and Denmark (see appendix 1).

In relation to the “project strategy“ the SBF tries to develop a market for a portfolio of related R&D projects, which the SBFs have carried out. This strategy can best characterize the SBF as a “science boutique” where the distinct aim is to sell or license projects to large pharmaceutical or chemical companies in a continuous stream. By this the science in itself are the product.

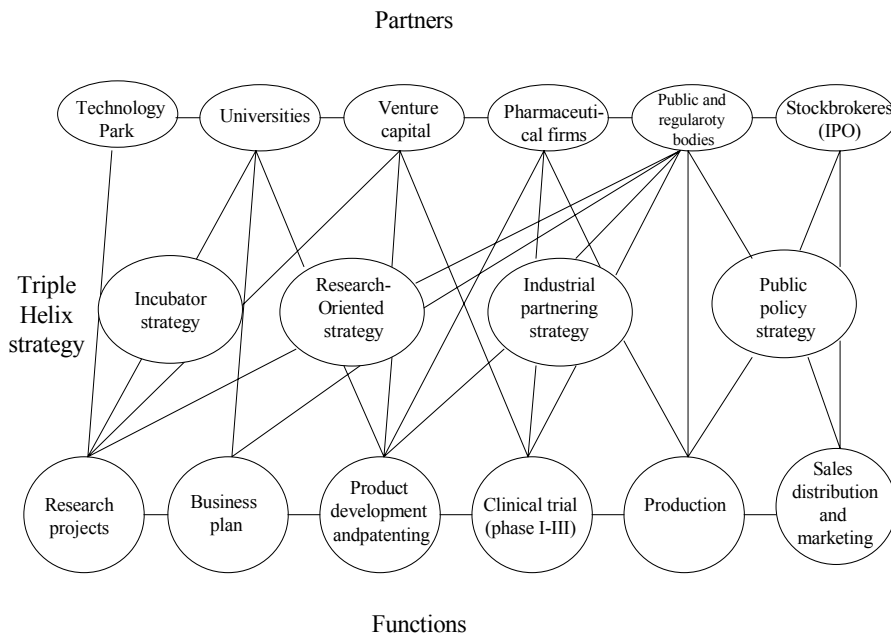
The “incremental strategy” has a slightly different strategic aspect where the SBF gradually learns and experience about the nature of the different task. The aim is stepwise to take command over more and more activities and by doing so fulfill the long-term goals of the company. The backbone of this strategy is to generate resources by selling projects, do consultancy services and by establishing joint ventures with larger firms. Through these partnerships the SBF gradually builds up more and more competencies in house deliberately protecting what are considered the long-term assets of the company.

The SBFs that follow the “vertical integration strategy” have a much more comprehensible strategy in the sense that the idea is to become a vertical integrated company that takes care of all functions from the development of new products, to the production, sales, marketing and distribution. Only few SBFs follow the vertical integration strategy due to the complexity of the technology, the regulatory aspects of getting a product approved, and of course the lack of resources to achieve the long term goal. Another important reason is that small firms often faces competence traps implying that they cannot build up an organization fast enough that can handle all aspects from research, production, marketing, regulatory aspects and distribution to capitalize on patents with a limited duration. This strategy means that the firm has to become a public traded company through an initial public offering (IPO) that challenges the routines for strategy formation, management and establishment of external networks.

Converting entrepreneurial strategies to network strategies

To investigate the dynamic aspects of network formation over time, the case analysis has to come to grips with the different types of decisions that are made at different points in time. An important analytical tool is the phase model that is outlined in figure 4. The phase model emphasizes the strategic options according to the different tasks and functions the small biotechnology firms carry out with different types of network partners. The different tasks that the firm has to take care of to launch a product are coupled to the types of partners with whom the firm fully or partly outsource the activities. The figure also link up to the four different network strategies and put them into chronological order. The steps from development to marketing only express some important steps on the ways to launch a product. The figure does not reveal anything concerning the importance nor the intensity in the network over time since this is a question that only can be investigated empirically. Even though the four strategies are put into a chronological order it is however important to stress that it is not a linear process. In between the different activities there will tend to be feedback loops that express the trial and error nature of the development process.

Figure 4: Linking actors to strategies



The research-oriented strategy is narrowly focusing on how a biotechnology firm transforms their research result into promising technologies, services or products. The incubator strategy is concerned with the problem of localization and how to come about specific types of managerial problem in the initial of forming a business venture. The industrial partnering strategy has to do

with how to overcome the problem of bringing the technologies from an experimental stage at a research lab to be able handle industrial processes and full scale production. Last but no least the policy oriented strategy focus attention to the problem of to have products approved by the public authorities.

It is important to stress that the four strategies are not fixed, but are to be regarded as step-wise processes that many biotechnology firms encounter in order to develop and commercialize their technologies. Therefore one cannot trace these strategies in any biotechnology firm. Instead they depict and emphasize specific modes of to deal with strategic problems that are solved by building up interorganizational relations at a specific point in time of the corporate history. The research-oriented strategy is narrowly focusing on how a biotechnology firm transforms their research result into promising. The incubator strategy is concerned with the problem of localization and how to come about specific types of managerial problem in the initial of forming a business venture. The industrial partnering strategy has to do with how to overcome the problem of bringing the technologies from an experimental stage at a research lab to be able handle industrial processes and full scale production. Last but no least the policy oriented strategy focus attention to the problem of to have products approved by the public authorities.

The research-oriented strategy (Calgene, Part One)

The fact that the firm started by doing contract research affected the way that Calgene sought to legitimize and organize its activities in later stages where it sought to control large markets segments in the tomato industry. It was doomed to fail and it failed. Until recently it was possible to download from Calgene's homepage the titles of all the scientific publications that the employees published in scientific journals in the period from 1981-1996, in total 247 published articles. It is interesting to look at the distribution of the research papers over the years. In 1981 and 1982 only one paper was published each year. Then the number of published articles rose to 30 articles per year in the period from 1985-1989. The number of articles that the Calgene researchers published then dropped to 10-15 articles in the period from 1989-96.²

The publication profile reflects that no scientific community had been established in the area of genetic engineering into plant research when the firm started. There were an absence of available techniques that were used to identify and characterize the specific genes in the plants, and the area also lacked scientific models of how the genetically modified plants reacted in the environment. Therefore, both a research community and the research field needed to be established and the only way to establish such communities was to establish the field through extensive contacts within the scientific environments in plant research. Thus, there was a hidden logic behind the corporate publication profile. First, the single researcher or a research firm has to demonstrate that they have developed research results that are of interest to the scientific environments in question. This ability is demonstrated through scientific publication. Secondly, publication is the ticket to be invited to meetings and conferences where the firm can present its research and the prospects of their business. It is in these meetings and conferences that new technological fields can be introduced and initiated.

Before a firm has relevant results to publish, it has to build up a common knowledge base of the firm. This period equals the first couple of years when Calgene only published a few scientific

² The homepage that was closed in the year 2000 and was originally found at: (<http://www.calgene-com.htm>).

papers. Afterwards there is a phase where the new scientific field are established, a period where the results from the research begin to show up on a regular basis, which corresponds to the phase from 1985-1988. In the third phase there are as many results published as in the second phase, but now the field is established and the commercial perspectives becomes visible and the firm becomes more product-oriented. In this phase the firm has to be careful not to expose too many articles that can reveal confidential development areas. This is seen in the period from 1989-1996 where the number of articles published by Calgene researchers fell dramatically. Another interesting detail concerning the period from 1992-1996 is that the articles published primarily are concerned with the applications and the commercial perspectives of the new techniques. This shows that the small biotechnology firms do corporate research and present in both academic and business oriented settings as a means of attracting industrial partners. In Calgene, the research activities had a dual function; the firm developed the basic scientific knowledge in a specific area and the firm commercialized its research. The firm could only fill the last role because the corporate researchers had the specific knowledge concerning the technological performance characteristics from their hands on knowledge in both the basic research and the commercialization of the technologies.

Calgene gained status both as a reliable business partner and as a serious partner in the establishment of research contracts by smoothing the lines between given presentations to a research community and given presentations of commercial nature. This routine was established so that the Calgene researchers had the main responsibility to attract resources through research contracts and partnerships with the industry to cover the expenses for their research projects. Thereby the researchers were given the ability to succeed in two worlds; the research world where it was the development of a research field or a community of practitioners of genetically engineering in plants and the business world where the Calgene researchers aimed to establish contacts to the industry to convince them that they should engage into strategic alliances and pay Calgene to do the research.

Despite the divisionalization of the corporate activities, the firm continued to establish research contracts using the same channels as the firm did when it was a research boutique. Each individual division, of course, made the contracts, but it was still the researchers that were in charge of the task. This meant that Calgene continued its mode of engaging in strategic alliances with large firms. Therefore, Calgene established alliances with firms such as Campbell Soup regarding the Flavr Savr™ tomato, Procter & Gamble in developing oils for detergents, Mobil Oil regarding motor oil, Rhone Poulenc Agrochemie regarding the development of cottonseeds and with Unilever. All of these contracts were initiated through personal contacts with key personal in the different divisions. As Calgene became more well-known in these firms, people from large firms came to visit the Calgene headquarter in Davis and shopped around in the different laboratories to search for projects that they could support and thereby access themselves in the development of their own products. The alliance with Procter & Gamble in particular shows that personal contacts initiated the establishment of formalized collaborative agreements. David Stalker, senior researcher, met by chance two managers from Procter & Gamble that had a huge budget to invest in interesting projects that the multinational could benefit from in the future. Stalker interested them in engaging in the Calgene oils division and a new partnership was established.

The interesting aspect of the research-oriented strategy in a network perspective is that the nature of the relationships that the company is developing are very much biased and guided by values that can be found in academia. It seems like all external relationships are to be developed from informal

and trust based relations where the partnering model is based on a vision of going on life-long journey with the partner. The way that the concept of trust is interpreted and taken for granted in these relationships means that the company after establishing its technological platform continue to develop its industrial partnering strategy in the same way. Although, the company change its overall strategy from being a contract research based company to become a vertical integrated tomato company the firm has great difficulties in establishing network relations that is not guided by these values. When we turn to the policy oriented strategy we will see that the way that Calgene approach the FDA (the Federal Food and Drug Administration) have the same character.

The Incubator Strategy, ThermoGen

In 1988 David Demirjian fostered ThermoGen Inc. together with his former professor from the University of Chicago, Malcolm Casadaban. The firm is located in Chicago, Illinois and until 1998 it rented its facilities from the incubator in the Chicago Technology Park. During 1998, the firm moved out of the incubator and rented new buildings in the Chicago Technology Park only a few blocks from its prior location. This move from the incubator both qualitatively and quantitatively led to changes both from a strategic and an organizational point of view.

The technological platform is developed from a specific type of enzymes and proteins, thermophilic organisms that are used as biocatalysts. The biocatalysts, the enzymes, can be used in industrial processes, for example in the development of foodstuffs, chemical products and pharmaceutical products. In relation to traditional industrial enzymes, thermophilic enzymes are more stable and can function in high temperatures. Hence fermentation processes can be carried through much faster than is the case with existing techniques.

The interviewees judged the role of the incubator in Chicago Technology as not only economically crucial. The firm definitely would not have existed without the incubator. The access up-to-date laboratory facilities in the initial phase would not have been possible to acquire for the USD 25,000 loan that was the company's seed money. Add to this the different types of consultancy services that the incubator offered or provided for the firm over the years.

For the members of the research team, the Chicago Technology Park did not appear immediately when they searched for facilities. They tried to locate in the incubator of the University of Evanston, but this incubator was not prepared for biotechnology firms. Afterwards the researchers tried to hire laboratory facilities at the University of Chicago. Thereafter they became aware of the Chicago Technology Park and were surprised of the capacity of the incubator. First of all there, were experienced entrepreneurs present from whom the researchers got valuable information. Some of these firms had also bought quite sophisticated equipment that ThermoGen could borrow and that helped to lower the costs.

Surprisingly, the access to these collaborative constellations in the incubator influenced the way in which ThermoGen structured and organized its activities. The firms inside the incubator for instance developed a flexible collaborative system, a sort of social security system that meant that the firms internally could hire and lend out human resources in periods with ups and downs. In that way a sort of internal fence against bad times was established, which made it possible to preserve jobs for the people that the companies had hired. At the same time this collaborative system meant that all the firms did not necessarily need to acquire all laboratory facilities. For ThermoGen the collaborative system meant that the firm could stay independent of external financial investment for a longer period of time. In bad times the internal security system was an advantage due to the

collaborative nature of the neighboring firms. In good times it was an advantage due to the possibility of hiring human resources from other firms, and borrowing laboratories and equipment from firms facing troubles. The people that a firm hired out for a period of 3-6 months meant that costs were kept low without having to fire them. For the loaner it meant that the firms were aware that the people that came to the firm were highly competent in the specific area where expertise was needed due to the close relationships between the incubator firms.

The issue that Demirjian saw as a real problem when located in the incubator was that at times the firms became too comfortable and therefore did not have any real incentive to find alternative locations even when they began to show economic results. This was reflected in the fact that the firm started in the incubator in 1988 and stayed there for 12 years. Initially the goal was to stay for no more than three years. It was prolonged to five years, but when I visited the company in late 1997 ThermoGen had been with the incubator for nine years. In spring of 1998 the firms moved to new facilities. Where are these facilities are located? Right, the company moved 50 Yards from the main entrance to the incubator building in the Chicago Technology Park!

Taking a network perspective on the initial phase of the history of ThermoGen, it is characteristic that a number of mediating actors (persons and institutions) are mobilized to find new partners and people that could further assist the business process. All these people have been very close related to the company's location in the incubator. The mobilization of actors and institutions have been crucial in helping ThermoGen overcome the problem of bringing the firm from a basic research unit to an entrepreneurial business seeking to develop its own products and services. It is my interpretation that many small biotechnology firms die out in the process of defining the business because they fail to get access to these mediating actors. Their search processes lead to dead ends that do not allow the small firms to develop a precise business plan and a corporate vision. In the case of ThermoGen, all necessary contacts to lawyers, accountant's etc. were initiated and organized around the Chicago Technology Park. These mediating actors were important in the beginning because the network of the founding researchers were by nature research related. The firm therefore lacked the specific knowledge on how to start up a new venture and how contacts were to be established concerning the structuring of the firm both internally and externally.

The Industrial Partnering strategy, Incyte Genomics

Incyte Genomics was founded in 1991 under the corporate name Incyte Pharmaceuticals. Incyte Genomics specialized in design, development and marketing of database based information products in the characterization and identification of genes and these genes proteins structure. This information is used by large pharmaceutical firms in the development of new types of drugs. The information products can also be used in the development of genetically modified plants where it is used to isolate specific genes. Incyte has copies of a huge number of gene sequences that they can supply their partners on demand. Thereby it is possible for the customers to develop new products: for example, the Flavr Savr™ tomato, in which the Calgene researchers isolated the gene that controlled when the tomatoes begin to rot. Incyte sells its products by engaging in partnerships with pharmaceutical firms who access to the database with non-exclusive rights. Incyte has developed a range of applications for the database that allows its customers search for active substances to develop new drugs. Incyte has also engaged in agreements with the following 18 firms that have bought access to the Incyte database systems: Abbott, Ariad, BASF, Bristol Meyers Squibb, Eli Lilly, Genentech, Glaxo Wellcome, Hoechst, Hoffmann La Roche, Johnson & Johnson, Monsanto, Novo Nordisk, Organon, Pfizer, Pharmacia Upjohn, Scheering, SmithKline Beecham and Zeneca.

These customers have 24-hour access to the database systems whereas Incyte serves the small firms by providing in-house consultancy service.

The company's primary income comes from partnership fees and from consultancy services for small firms that do not have the interest in or the resources for an exclusive access to the database. These firms ask Incyte to take care of search processes. In the future, Incyte will therefore generate income from royalties that the firm gets from products that its partners have developed from the firms gene sequencing systems. To preserve and further develop the services that the firm provides, Incyte has bought up two small biotechnology firms, Genome Systems in St. Louis and Combion Inc. in Pasadena outside Los Angeles. Moreover, Incyte has developed a joint venture company with the aim to develop new diagnostic products to direct the firm's competencies in future.

The first two partnerships that Incyte established were the agreements with Pfizer and Pharmacia & Upjohn. These two firms got stock options as part of their agreements; thus these two firms in 1998 owned 6.7% and 7.5% respectively of the corporate stocks before the stock issue in 1997. In spite of the fact that these two firms have ownership in Incyte, all partnership agreements with other firms are established with non-exclusive rights so that Incyte has no special ties to any of its customers. None of the partners can say that they have special advantages/disadvantages compared to the other partners. Another reason that access to the databases is given on a non-exclusive basis is to avoid letting one of the major partners buy up the firm to keep the technology for itself. This aspect of the agreements is maybe also the primary reason that the first two partners took an equity position because they may have feared that they could have been used as a sales window to sell off the company afterwards without having had an opportunity to make an offer on the firm themselves.

Incyte Genomics engages in two types of partnership agreements with firms: 1) Firms that buy access to the databases, and; 2) firms that deliver/sell data to the databases. The latter type of agreement is Incyte's strategy to form partnerships with as many relevant firms as possible and have them to deliver the data that Incyte afterward structures and packs into the databases. These partnerships concern the input to the database or bioinformations systems. These information systems are later indexed in interests groups such as animals, plants, bacteria etc.

Consistent with the experiences faced by the firms in my sample. For instance did Incyte experience that as the firm legitimizes its technologies there is no longer a question of how to attract new partners, but rather that interested partners contact the firm to form partnerships or ask for their consultancy services. In this situation the firm faces a need to make continuous evaluations and reviews of technologies and techniques developed by small biotechnology firms that could be interesting to include into the databases. This very fact changed the way that the firm organizes its external relations. Previously, Incyte often attended research conferences to promote the firm and present the services that it could provide. Today the promotional work is much more focused around the development of new partnerships.

A third type of partnership that was developed in 1997 was a joint partnership with the pharmaceutical firm, SmithKline Beecham, in the formation of a joint venture firm, diaDexus, that develops molecular diagnostic products. The firm is located in Santa Clara, 10 miles south of Palo Alto. The agreement between SmithKline Beecham and Incyte is that the large partner gives diaDexus an exclusive license to utilize a range of diagnostic tests that SmithKline Beecham bought the rights to from a third biotechnology firm, Human Genome Science, whereas Incyte provides access to the firm's bioinformation systems on a non-exclusive basis. The partnership should reduce

the risk of failure because each of the firms adds some very scarce competencies. Incyte adds some very important support functions, whereas SmithKline Beecham has the competencies that make it possible to have the diagnostic products approved and marketed.

In a network perspective it seems like the industrial partnering strategy is an almost endless opportunity seeking formula for developing a small biotechnology venture. Having concluded that it is also fair to say that the strategy is not very easily copied or transferred into other types of biotechnology firms. Bioinformatics and genomics firms have a technological platform that allow them to act as a highly advanced service company and at the same take out specific projects and develop them into new business ventures e.g. joint venturing in collaboration with their large industrial partners. This means fast growth both in terms of employees and in the numbers of partners. In turn this raises a questions of a company's ability to manage this growth since their must be an upper limit of how many partnerships you can be committed to at same time.

The policy oriented strategy, Calgene, Part Two

In the late 1980s, Calgene decided to develop its own products instead of continuing to be a research boutique; this decision meant that the firm started new activities to be well prepared for the happy day when the Federal Drug Administration (FDA) would approve the new products.

A decisive parameter for being able to attract external investors, e.g., venture capital firms, is that small biotechnology firms start clinical trials on at least one product. This situation has developed over the last five years. Before that time, going into the phase of clinical trials meant that it was time to consider introduction on the stock market. This change, viewed from the perspective of entrepreneurs, also in part explains the relative success of the SBIR program. This program seems to have bridged the gap between the development of business plans and related R&D activities, on the one hand, and the changed strategies of venture capital firms towards the biotechnology industry on the other hand.

The FDA is seen as either the worst nightmare of a bureaucratic organization or as a relatively open organization. In principle the FDA is performing an impossible task because it is unable to develop the competencies and skills necessary to keep up with the development of new products and technologies in the industry. In consequence, getting biotechnological products approved is considerably more time consuming than getting traditional products approved. This causes difficulties for the companies because they are almost set on hold while waiting for the FDA approval. Therefore, small biotechnology firms in general must display a more proactive attitude toward the FDA while the clinical trials are going on instead of sitting back and waiting for the FDA decision. One example of the negative attitude toward the FDA appeared during the interview with Dr. David Englemann, a Stanford professor who has formed 4 biotechnology ventures while Carolyn Hayworth accounts for the policy strategy followed by Calgene when having the genetically modified tomato approved.

I hate the FDA. The FDA is a barrier to entry. The FDA exists to prevent potentially toxic drugs or toxic or dangerous devices from getting to market. The FDA doesn't get any credit if a marvelous new drug is discovered and approved. But they get blamed if a marvelous new drug is approved and it turns out to have unanticipated toxicity. For that reason the FDA's sole purpose for existing is to prevent drugs and devices for getting approved because they only get blamed if

something goes wrong. They don't get any credit if things go right. It takes ten years on average for a drug or device to be approved and it cost hundreds of millions of dollars. I see it as a negative incentive for the small company. It is one of the reasons why so few drugs are approved every year - because the FDA makes it so difficult. I think that the companies themselves should be responsible for assuring the safety of the drugs and the efficacy to the maximum of extent possible. But I believe in letting the market forces determine that. I think that there have to be some basic safety rules but the kind of testing that is required of the FDA, I don't agree with it. I think it is overkill.

Dr. David Englemann, Director of the Stanford Blood Center

We have an excellent relationship with the FDA right now. Not that they have given us anything as quickly as we wanted, but part of the development of this technology was that we wanted to be the first. We wanted to be the pioneer in this technology and get through the FDA and help the FDA to form the policies for these types of products, and that is what we have done. In 1992, the FDA, after we had presented our data, developed a policy for the development of new plant varieties and they included genetic engineering. Calgene has been instrumental and helped them to put together that policy. We had wanted to demonstrate the effectiveness to validate that the government has oversight in this area, and that their oversight is appropriate, and that is what we have done. They are validating our products as much as we are validating their agency in the area of biotechnology. So it is a kind of I help you, and you help me.

Carolyn Hayworth, Manager of The PR Department, Calgene

As indicated Calgene at a very early point by the end of 1988 formed its initial relationships with the FDA. The strategy was to get actively involved in the specifications of the rules and regulations that the FDA would demand of genetically modified food products. At that time the FDA had not developed a set of rules and regulations in this area because no companies had contacted the FDA to have such products approved. Therefore, Calgene was the first company that called for rules and regulations. This implied that Calgene, by its own account, established a very open dialogue with the FDA, and that Calgene assisted the FDA in the development of the policy that the FDA published in 1992. This policy was made public two years after Calgene had posted its first application for product approval of the Flavr Savr™ tomato to the FDA. This first application was renewed in 1991 and forced the FDA to carry out a policy and a set of rules and procedures aimed at the genetically modified food products that began to show up in 1991.

The approvals of the product took more time than expected. Eventually Calgene got the tomato approved in the beginning of May 1994 and Flavr Savr™ was the first genetically modified fresh fruit or vegetable product that was approved for human consumption by the FDA. The final approval was very positive from the perspective of Calgene because the FDA evaluation of the product concluded that the Flavr Savr™ tomato did not differ noticeable from traditional tomatoes on a number of characteristics. Therefore Calgene was not forced to put a special sticker on the tomatoes showing that the product was genetically modified. The selling of the tomatoes began three days after the approval in supermarkets in Illinois and Northern California. The sales figures were positive, but Calgene did not earn any money because it did not had access to enough square acres to grow the tomatoes and therefore the firm could not supply the supermarket/customers with a stable delivery and a sufficient quantity of the new tomatoes.

When the FDA had approved Flavr Savr™ in the beginning of May 1994, Calgene was prepared both internally and externally to take advantage of its rights to sell the product on the market. Despite the fact that the FDA did not find that the product differed from other tomatoes available on the market, Calgene changed the brand name of the tomato. Instead of the well-known name from the media, Flavr Savr™, the tomato was given a more neutral and aggie-like name: “MacGregor®.” According to Martineau the name was hint from the childrens song “Old MacGregor has a farm” (Martineau, 2001).

Part II of the Calgene case shows how the company still uses the same gameplan for building up relationships when approaching the FDA for the final product approval. In Belinda Martineau’s book: “First Fruit” she describes also how it was the senior researchers into Calgene that were given the task first to have their technological concept approved and it was the same group of researchers that eventually putted together the final application and had the tomato approved while the business development people and the chief regulatory personal were given tasks in order to promote the first genetically modified fruit for human consumption in different types of fora of consumer rights groups, supermarkets etc. (Martineau, 2001)

Implications of partner analysis – by the way of a conclusion

Theoretical contributions and future directions

The article show that the diversity, heterogeneity between the four partnering strategies make them almost incompatible. At the same time they show that the inital networks that the companies form create paths for the future ability to form new partnerships. Therefore it could be interesting to investigate the path dependent nature of these networks and try to link this analysis to the ongoing research discussions and path dependence and path creation in the area of economics, econmic sociology and technology sociology (Garud & Karnøe, 2001; Rosenberg, 1994)

Managerial Implications

This discussion points to several possible implications for business people, policy makers and academia. For business people, particularly those considering starting their own business, it seems to be of vital importance of the challenges, the norms and values that is bounded to the initial arguments and modes of engaging in external partnerships. To the extent that we can argue that organizational routines are under construction in this stage of corporate life, the article demonstrates how valuable resources are mobilized in a variety of different external networks. However, the mode of how to establish network relations can be difficult in the later stages of corporate life if these new network is guided by a different set of values and norms. This is due to the fact that networks often are of an exclusive nature, calling for strong relationship building activities, management of reputation, etc.. Moreover, the extent to which the importance of these networks is acknowledged and is in control of valuable routines, support the idea that the development of entrepreneurial abilities with respect to firm creation hinges on a period of “hanging around”, i.e. building relationships and contacts. Several pieces of anecdotal evidence from my studies in the field support this notion.

For policy makers the often rather one-sighted focus on solitary entrepreneurs and how to pick these winners and nurture them may need to be replaced with a stronger focus on the importance

of solidarity networks and the process of trust-building among entrepreneurs. Skills for business start-ups are available in network contexts and their importance for generating more business start-ups are presently underestimated in most industry policies we know of.

Finally, for academia it is necessary not only to acknowledge that networks are important in processes of firm creation but also to understand what they actually are able to take care of in business creation processes. A stronger focus on the role of the systemic nature of business creation processes is called for, in order to explore the division of labour actually taking place in the micro cosmos of business creation.

References

- Barley et.al. 1992. *Strategic Alliances in Commercial Biotechnology*. in Nohria, N. & Eccles R.G. ***Networks and Organizations - Structure Form and Action***. Boston, Massachusetts: Harvard Business School Press.
- Constant II, E. 1984. Communities and Hierarchies: Structure in the Practice of Science and Technology. Laudan, R (ed.). ***The Nature of Technological Knowledge. Are Models of Scientific Change Relevant?*** Dordrecht: D. Reidel Publishers
- Constant II, E. 1987. The Social Locus of Technological Practice: Community, System or Organization. in Bijker W., T. Hughes, & T. Pinch (eds.) ***The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology***. Cambridge: MIT Press
- Daly, P. 1985. ***The Biotechnology Business***. London: Frances Pinter
- Garud, Raghu, Peter Karnøe (eds.) (2001): ***Path Dependence and Creation***. Mahwah: Lawrence Erlbaum Associates, Publishers
- Kenney, M. 1986. ***Biotechnology: The University Industrial Complex***. New Haven: Yale University Press
- Kreiner, K. & M. Schultz 1993. Informal collaboration in R&D. The Formation of Networks Across Organizations. ***Organization Studies*** Vol 14. No 2, 189-209
- McKelvey, M. 1996. ***Evolutionary Innovations –The Business of Biotechnology***. Oxford: Oxford University Press
- Norus, J. 2002. ***Biotechnology Organizations in Action – Turning Knowledge into Business***. Progress in Biotechnology Series, Volume 20. Amsterdam: Elsevier B.V.
- Orsinigo, L. 1989. ***The Emergence of Biotechnology - Institutions and Markets in Industrial Innovation***. London: Frances Pinter.
- Pfeffer, J. & Salanzik G. 1978. ***The External Control of Organizations. A Ressource Dependence Perspective***. New York: Harper & Row Publishers.

- Pfeffer, J. 1987. A Resource Dependence Perspective on intercorporate relations. In Mizruchi, M. S. & Schwartz, M. (eds.): *Intercorporate Relations: The Structural Analysis of Business*. Structural Analysis in the Social Sciences No 1. Cambridge: Cambridge University Press
- Powell, W. W. et al. 1994. *Technological Change and the Locus of Innovation: Networks of Learning in Biotechnology*. Working Paper. Tucson: Department of Sociology, University of Arizona.
- Powell, W. W. et al. 1996. Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly*, 41: 116-145.
- Powell, W.W. 1998. Learning from collaboration: Knowledge and networks in the biotechnology and pharmaceutical industries". *California Management Review*, 40: (3) 228-263.
- Robbins- Roth, C. 2000. *From Alchemy to IPO – The Business of Biotechnology*. Cambridge, Massachusetts: Perseus Publishing
- Rosenberg, Nathan (ed.) (1994): *Exploring the Black Box – Technology, economics, and History*. Cambridge: Cambridge University Press
- Seely Brown, J. & P. Duguid 2000. *The Social Life of Information*. Boston, Mass.: Harvard Business School Press
- Wenger, E., R. McDermott & W.Snyder 2002. *Cultivating Communities of Practice*. Boston, Mass.: Harvard Business School Press
- Zucker, L. & M. Darby 1995. Individual Action and Demand for Institutions: Star Scientists and Institutional Transformation. *American Behavioral Scientist* Vol 40/No. 4 1997: 502-513