Dynamics of Alliance Networks: Evidence for Development Phases Based on a Sample of Young Nanotechnology Companies

Björn Klocke
Institute of Technology Management
Technical University of Berlin
Hardenbergstr. 4 - 5, HAD 29, 10623 Berlin, Germany

Tel: +49 160 755 9474
Fax: +49 160 13 755 9474
Email: bjoern.klocke@tim.tu-berlin.de

Hans Georg Gemünden (corresponding author)
Institute of Technology Management
Technical University of Berlin
Hardenbergstr. 4 - 5, HAD 29, 10623 Berlin, Germany

Tel: +49 30 314 26090
Fax: +49 30 314 26089
Email: hans.gemuenden@tim.tu-berlin.de

Thomas Ritter
Department of International Economics and Management
Copenhagen Business School
Howitzvej 60
2000 Frederiksberg, Denmark

Tel: +45 3815 2518
Fax: +45 3815 2500
Email: tr.int@cbs.dk

BJÖRN KLOCKE, PhD student at the Institute of Technology Management at the Technical University of Berlin, Germany.

HANS GEORG GEMÜNDEN, professor at the Institute of Technology Management at the Technical University of Berlin, Germany.

THOMAS RITTER, associate professor at the Department of International Economics and Management, Copenhagen Business School, Denmark.

Competitive paper submitted to the

18th Annual IMP Conference at the Dijon-Burgundy Graduate School of Management

September 5-7, 2002 in Dijon (France)

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Abstract

During the last years, inter-organizational cooperation and strategic alliances of companies received both managerial and academic attention. In many cases, the alliances of a firm can only be understood as an ensemble forming the alliance network of the given entity. Alliance networks are a complex phenomenon that still poses many open questions. One of them is how to describe and explain their dynamics.

This article discusses the first results of our research on the dynamics of alliance networks. We build our effort on literature about alliance formation during the life-cycle of the company. Based on exploratory interviews with Nanotechnology companies, we developed a general phase model for technology-driven start-ups. The model distinguishes technology and market activity phases of exploration and exploitation and links those phases with the formation of different types of cooperation. Our results refine the understanding of network development and of its business-related drivers.

Introduction

Inter-organizational cooperation and alliances of companies are topics that receive lots of managerial and academic attention. In many cases, the alliances of a firm can only be understood as an ensemble forming the alliance network of a given entity. Today, the literatures about alliance networks adds up to a substantial amount of articles most being published during the last ten years. So far many diverse factors are known that shape alliance networks. Furthermore, many network properties that influence business success were identified. It became clear that alliance networks are a multi-facetted phenomenon.

According to Gulati (1998) one of the main objectives of current research on alliance networks is to understand their dynamics. Little is know about how networks evolve, change and fall apart and what drives such processes. Network dynamics promises to be a topic of interesting insights but is complex and difficult to handle empirically. Researchers need to obtain longitudinal data about all alliances of the focal companies and numerous factors of possible influence on the network.

Nevertheless, there is a significant number of single case studies about the dynamics of alliance networks that give first evidence about growth, path dependence, change processes, etc. (e.g., Hertz 1996, Lundgren 1992). The few time-dependent factors that were investigated systematically with quantitative studies are firm age done by Oliver (2001) and embeddedness in the alliance network itself done by several authors including Gulati and Gargiulo (1999). We build on Oliver's study that proposed learning phases of exploration and exploitation, and will concentrate our research effort in this paper on the following questions: *Which relevant phases of firm development can be distinguished theoretically and empirically? What is their influence on network dynamics?*

Many previous studies on alliance networks took the Semiconductor or the Biotechnology industry for sampling. In this paper, we investigate the alliance behavior of Nanotechnology companies. Nanotechnology is a buzzword summarizing different technologies that deal with dimensions below 100 billionths of a meter (100 nanometers), which is about the dimension of large molecules. Nanotechnology comprises quite different sectors, is heavily dependent on cooperation yet has no established network structures and, as consequence, its alliances are very dynamic. Hence the industry presents an interesting new test case for research on network dynamics.

Business relationships, alliances and its networks

A business relationship is characterized by a long-term exchange between two organizations. Hereby, exchange may include goods, financial resources, ideas, product and market information. Over time, the two organizations may adapt their exchange to each other and thus, a certain degree of institutionalization and routinization occurs (IMP Group 1982, Ford 1980, Dwyer et al. 1987). It has been shown that in and for close relationships, trust and commitment between the parties involved plays a central role (e.g., Wilson 1995).

Business relationships might become the starting point for more intense collaboration. In literature, the terms "alliance" or "strategic alliance" are used to describe collaboration based on certain agreements or specified goals. Gulati (1998) defines "strategic alliances as voluntary agreements between firms involving exchange, sharing, or co-development of products, technologies, or services." Most authors (especially in the U.S.) use the terms alliance and strategic alliance interchangeably. In this paper, we will take on a pragmatic standpoint and use the word alliance instead of strategic alliance in the definition of Gulati.

While different inter-organizational theories might be used to explain the formation of alliances (Sydow 1992), it is the resource-based view and the knowledge-based view that are most often applied today. The transaction cost approach proposed by Williamson (1991) was popular in the early nineties but is rarely used today because it failed to explain abundant partnering in high-risk industries like Biotechnology. In the resource-based view, firms might use alliances to access complementary resources and the leverage the internal resources better (Eisenhardt and Schoonhoven 1996). According to the knowledge-based view, firms might use alliances to access knowledge, then internalize it by organizational learning, and finally use it (Cohen and Levinthal 1990).

Citing Gulati (1998) again, alliances "can occur as a result of a wide range of motives and goals, take a variety of forms, and occur across vertical and horizontal boundaries." In the past, authors used various dimensions to classify and compare alliances. Typical dimensions being used are properties of the relationship like governance type (Contractor and Lorange 1988, Hagedoorn 1990) and contact intensity (Zhao and Aram 1995). Other authors identified the influence of dimensions that refer to properties of the partner like his function in the value chain (Gemünden et al. 1992).

A firm has normally a set of relationships and these relationships are interconnected (Blankenburg and Johanson 1992, Cook and Emerson 1978, Ritter 2000). This wider structure

of connected relationships has been termed network (Håkansson and Snehota 1995). Wasserman and Faust (1994) define a social network as a "finite set or sets of actors and the relation or relations defined on them". We are primarily interested in alliance networks, which consist of organizations (typically companies) as actors and the alliances among them as relations. In addition, we have a look at the business networks, which – in the definition of Anderson et al. (1994) – are given by sets of connected business relationships.

Dynamics of alliance networks

Dynamics of alliance networks refers to changes in the set of alliances that are present in a network. Dwyer (1987) and Larson (1992) showed that each business relationships and alliances follow typical development phases themselves. In the following, we will not deal with this additional dimension of change but concentrate on the overall changes of the alliance network.

There are different approaches to investigate the dynamics of alliance networks. One approach is to treat large networks as one system. Usually this research focused on special phases of the network development. Main themes are their formation (e.g., Kreiner and Schultz 1993, Doz et al. 2000, Human and Provan 2000), their intrinsic development and change (e.g., Håkansson 1992, Lundgren 1992, Hertz 1996), and adaptation processes after external shocks (e.g., Kash and Rycoft 2000, Luthardt 2000). Unfortunately, much of this research is rather descriptive and difficult to generalize.

Complexity theory, a descendant of evolutionary theory, provides insights into the mechanisms that establish order in the evolution of networks. According to Kappelhoff (2000), the general idea is that order is created by both internal forces (self-organization) and external forces (selection). Complexity theory might provide a theoretical base for research on large networks with many actors. Based on the theory, Wilkinson and Wiley (2000) developed models of alliance networks (so called complex adaptive systems) and tested their behavior in computer simulations. So far, complexity theory resulted in discovering some general mechanisms in networks that were used to explain industry phenomena (e.g., Browning et al. 1995) yet it seems again hard to understand the complex development of networks on the network level.

There is a string of studies that follows a somehow different approach by giving most attention to firm-level effects. They take the companies one by one and investigate its networking behavior over time. A number of authors including Kogut et al. 1992, Powell et

al. 1996, Walker et al.1997, Gulati 1999 and Ahuja 2000 analyzed the formation of single new alliances under the influence of the existing network in many different industries. They found that firms tend to prefer those partners for new alliances that are in their established network or at least connected to it over only a few ties. This formation behavior leads at industry level to cliques that are strengthened over time.

Hite and Hesterly (2001) discussed the evolution of firm networks of business relationships on a theoretical basis. They propose that emergent firms have primarily socially embedded ties, form rather coherent networks and underlie path-dependent network growth. They argue that at transition from emergent stage to early growth of the firm the network composition changes to a balance of embedded and arm's length relations, the firm exploits structural holes and the networks becomes intentionally managed.

Oliver (2001) looked at a different firm-level effect in Biotechnology. She analyzed alliance formation in each year of the companies' life and could show that formation probability is a function of firm age with inverted U-shape for the first eleven years after which a second rise takes place. In addition, she showed that failure to form new alliances results in organizational death. Oliver built on work of Nootebohm (1999) and interpreted the varying levels of formation activity as cycles of product learning. First, in an exploration phase, the companies explore new and innovative knowledge, partly by accessing it via alliances. Then they internalize and integrate the knowledge in an exploitation phase.

Initial Proposition 1: Firms undergo learning phases of exploration and exploitation.

Phase and life-cycle models are abundant in literature. An often cited corporate life-cycle model is proposed by Miller and Friesen (1984), who described five phases from birth to decline. The growth time of small businesses after birth is described in more detail by Churchill and Lewis (1983). They propose a model with five stages, which was later empirically tested by Eggers (1994). In the Marketing literature, product life-cycles are a common tool. Oliver (2001) associates the learning cycle with both organizational life-cycles as well as product life-cycles. However, they refer to different phenomena (alliance formation activity, company features including total sales growth, and product sales) that show the cyclical behavior and typically have different cycle periods. Additional thoughts are still necessary to relate the models with each other. Nevertheless, we hypothesize a general influence of development phases on alliance network dynamics.

Initial Proposition 2: Certain firm activities follow rather phase-driven than linear patterns. These phases have an impact on alliance network dynamics.

Concluding the literature review on network dynamics, approaches that analyze firm level effects seem to be most promising to give new insights. Hence, we will target firm level effects in our study as well. Until now, the available literature leaves many questions on network dynamics unanswered so that we use a rather exploratory empirical approach.

Data and method

Methodological approach

We decided to tackle the research questions with short explorative, theory-building case studies. Concerning the methodology we conducted the case studies in rather rigorous manner following suggestions of Yin (1984) and Eisenhardt (1989).

Sample

Nanotechnology is a diverse and young field of high-technology that recently faced dynamic business activities. It comprises a vast number of physical and chemical techniques to manipulate matter at tiny dimensions – per definition below 100 nanometers, which gave these technologies its name. So Nanotechnology, like Biotechnology, is not in industry itself but rather a set of more or less related applications, i.e., sectors.

In our industry analysis we found that there are roughly 300 companies in Germany that develop or use Nanotechnology products. About 100 of them are rather small companies that were founded during the last ten years, the rest are large corporations and established medium sized enterprises. Most of the companies depend strongly on others, and there is lots of cooperation in Nanotechnology.

We analyzed companies that apply Nanotechnology at a significant extent, but it is not necessary that they have already sales with these products or that Nanotechnology products are their only business. In the case of bigger companies we focused the interview on the business unit that dealt with Nanotechnology. We selected cases that covered a big range of ages and diverse sectors. The final sample consisted of 20 companies from Germany and additional 2 companies from Switzerland.

Getting the data

Little of the data we needed is available in public because the industry is quite young and fragmented. So we had to rely on multiple data collection methods. The main information source were interviews of 0,5 to 1,5 hours, which we conducted with suitable representatives

of each of the companies. The interviews were semi-structured. We mostly followed a general structure but explored new emergent topics and set focus on most important subjects shaping each company. In most cases, the atmosphere during the interviews was open. Four companies held back certain information while arguing for confidentiality reasons.

We used additional data sources to supplement the interview data afterwards. Those sources were: interviews with science and industry experts, database of the Federal Ministry of Education and Research of Germany (BMBF) about funded projects, database of the German Patent Office, Internet homepages, memberships lists of associations, articles in specialized Internet journals, and company brochures.

Data analysis

We used the interview data and the additional information to build a company database containing all 22 cases. The database has 50 fields for each company, which represent three main categories of information: existing network of the company (alliances, business relationships, personal contacts), the way alliances were formed and the company background. Subsequently, we used the company database for various cross-case analyses.

Results

Business relationships and alliances

Almost all firms in our sample depend on partners and collaborate frequently with research institutes, suppliers, companies offering complementary parts, customers and sales organizations. Most cooperation agreements are of short duration and often project-based, and companies usually avoid long-term alliances to keep strategic flexibility given their uncertain environment. Partners are changed quite often if it turns out that they cannot fulfill requirements. However, partner-specific design choices and adaptations sometimes induce lock-in effects. So far, acquisitions - mostly done by big corporations - play only a minor role of cooperation.

In the interviews it turned out that alliances are usually used and maintained by two different departments (i.e., persons) in the company, which is R&D and Marketing/Sales. Their alliances are directed towards technology (input) and towards the market (output), respectively. In the following, we will refer by "technology alliances" to alliances for know-how supply and product supply as well as technological cooperation with complementary

providers and by "market alliances" to alliances with complementary offers, alliances for marketing and sales and alliances with customers.

Proposition 1: Technology and market directed parts of the alliance network can be distinguished, and their development might differ.

Another finding of the interviews was that companies distinguish business and alliance partners mainly based on commercialization (research institutes vs. companies) and on function in the value chain (knowledge and product suppliers, competitors, complementary providers, wholesalers/brokers, marketing support, customers). Tables 1 and 2 list the typical forms of cooperation that we found for each combination of these two attributes. The form of collaboration differs a lot depending on the function of the partner in the value chain. The conceptual distinction of technology and market alliances might imply some role overlaps because competitors and companies developing complementary technologies might provide both technology and market functions.

Network dynamics

After having recognized that alliances are mainly used for the two business functions R&D and Marketing/Sales, we tried to apply an exploration-exploitation framework for the two business functions separately. Oliver (2001) applied the framework to describe the formation pattern of alliances ex post (and without differentiating for functions). In contrast, we started with the framework ex ante to analyze the different business activities in our sample and then to deduct alliance formation behavior.

At first, we need to introduce a few new terms. We define t*echnology exploration* as R&D activities that result in a fundamentally new product. This includes basic research, construction of an innovative prototype and developing first large scale production technologies. *Technology exploitation* comprises all R&D activities that apply existing knowledge to modify and improve existing products. In our definition, *market exploration* is Marketing and Sales activities that aim to understand new markets and to introduce products to them. This includes research on the basics of the market, test sales to first customers, and focused activities to build up a customer base. *Market exploitation* refers to activities that use an existing customer base to create and grow sales by fulfilling the customer needs.

Next, we trace the typical evolution of the companies in our sample. Figure 1 presents the possible combinations of technology and market phases in a two-by-two matrix, and table 3 describes the actual business activities of the companies for each development stage. All

interviewed firms except the wholesalers and distributors of the sample (three in total) fit into the framework. Companies start with technology exploration, then market exploration follows. At later stages, technology exploitation begins, followed by market exploitation. The further development is rather individual.

Proposition 2: Technology and market activities of young technology-based companies follow the same pattern of first exploration and then exploitation. Market exploitation begins only after technology exploitation has already started.

In general, the first cycle of stages 1 to 4 that was described above seems to be quite stable before the development of companies splits into different paths (see figure 1). All companies in our sample (except wholesalers/distributors) started with technologies not customers. As consequence, the main strategic interests in partnering that young companies report is to find partners and customers that have a need for the existing technology capabilities or product of the young company. Older companies might either look for customers that need existing technologies or, the other way around, for new technologies satisfying known customer needs.

From the analysis a four-stages model follows for the development of the firm and formation of new alliances (see figure 2). The model builds on the development stages in table 3 that refer to generic successive strategic goals of the companies: Push the main product idea forward, prepare suitable production and make first cash to survive and to get to know the market, get into real business by a systematic exploration of the market, and become an established and profitable player while securing and expanding the business.

Propostion 3: Young technology-driven companies develop in a sequence of four distinctive activity stages that are associated with distinctive strategic goals.

In the next step of the analysis, we tested the relation between business activities and alliance formation. First we defined the development stage of each company based on reported general activities and strategic interests. In our sample, all stages after foundation were covered: We found five companies at stage 2, six companies at stage 3, three companies at stage 4, and five companies at a stage of further development. No company was still at stage 1.

Then we compared the recent alliance formation activities of each company with its development stage. Figure 2 summarizes the typical alliances that were formed at each stage. Many technology alliances are formed at stages 1 and 2 for technology exploration, and important market alliances are formed at stages 2 and 3 for market exploration. In most cases,

exploitation phases cause less alliance formation activity. Of course, there are sector specific differences between the companies. For example, companies producing Nanotechnology paint use in general few technology alliances with research institutes because product technologies in this area are already quite mature. However, the relationship of main business activities and alliance formation is evident. In other words, if new alliances are chosen they usually fit to the main predicted needs of the company at that time.

Proposition 4: Formation of technology directed and market directed alliances relates directly to the activity phase the young company is in. Formation behavior differs among the four development phases.

Our findings replicate Oliver's (2001) proposition that for exploration fewer new alliances are needed than for exploitation. In our model, the first cycle of formation activity rise and fall is about the time until stage 4. For our Nanotechnology sample, companies at stage 4 are between nine and twelve years old. This is about the cycle length Oliver (2001) obtained for Biotechnology firms, which is roughly eleven years.

Oliver (2001) observed in her data a second rise of alliance formation activity in years twelve and following. She hypothesized that this rise might be attributed to a second cycle. According to our stage model there are innovation cycles taking place after stage 4 but they seem to be less pronounced and have very individual characteristics. We had five companies of our sample in the period after stage 4 called "further development". These companies were 12 to 50 years old and had many products in different phases of product life. Consequently, in these companies exploration and exploitation activities happened at the same time. We could not observe a cyclical alliance formation pattern at these older companies, which might indicate that there is no clearly defined second cycle, which Oliver proposed.

Conclusion and future research opportunities

Conclusion

We started with the research questions, which relevant development phases of young technology-driven firms can be distinguished, and what their influence on network dynamics is. We used explorative interviews with diverse Nanotechnology companies as main empirical input. In an intermediate step of our analysis, we showed that there is a big variety of alliances used by young companies, and that they serve either technology or market purposes. Based on this distinction, we developed a framework that traces the typical evolution of

business activities, and linked it to a stage model that describes the sequence in which certain technology-related and market-related alliances are formed.

Our analysis allowed propositions about the order in which new alliances are formed and about the underlying strategic needs that drive the development. Thus the stage model becomes a tool to explain and predict patterns of alliance formation over time. Accordance among the various sectors in our sample and with the work of Oliver (2001) suggests that the model is applicable to all high technologies like Biotechnology, Precision Optics, Semiconductors, Nanotechnology etc., in which businesses start rather with technological ideas than with customers. In addition, our model seems to be robust enough to capture companies independent of their strategy. Strategy types (Gemünden 1995) might be less pronounced less mature industries anyway, i.e., differences in strategy might be small in young industries because the strategy type of all companies is "pioneer", thus the same. Of course, there are some limitations to the model. Our interviews suggest that it applies to producers but not to wholesalers, distributors, other service businesses and business development units.

Our findings support and extend previous work about network dynamics done by Oliver (2001). The accordance of basic findings was not obvious upfront because we looked at different technologies and used a different empirical approach. Oliver described overall alliance formation intensity as a function of time. We could refine this view by identifying the different types and functions of partners used over time and by confirming their role in the strategic context of the company. In addition, we could qualify different phases of technology exploration and exploitation as well as market exploration and exploitation. This result sharpens the phase concepts that Oliver (2001) introduced yet did not tie together.

Research implications

Our results open up a few new avenues for further research. One question is whether the average time to reach stage 4, which Oliver (2001) and we report to be of about eleven years, is a constant or rather variable depending on internal and external factors influencing the growing company. An initial screening of our data suggests that there is big variance among the companies in timing the phases.

Another open aspect is the quantification of the stage model. We determined the stage each company is in on various, rather qualitative measures. A quantitative interpretation of the

stages might allow to determine precisely the position of companies inside the stage and to test the stage model more rigorously based on longitudinal data if available.

The two-by-two exploration-exploitation framework does not dependent on alliance considerations, and its implications extend network dynamics. The typical path of young companies gives insights into management processes of young technology-driven companies and might be fruitfully combined with existing growth models (e.g., Churchill 1983 and Eggers 1994) to analyze and predict company development and related management issues.

Our findings underline the importance of partner type and partner function for alliance formation. However, most studies about high-technology companies using network analysis neglect this influence and treat all actors the same. Consequently, such network analyses face strong limitations. Kogut (1992) used network analysis in Biotechnology for two separate sets of actors, namely incumbents and start-ups. Network analysis might use such methods more often in the future.

Management implications

Our results point to some implications for the management of young high-technology companies. In management practice, the stage model might be used as a tool for proactive, more intentional management of alliances. In general, managers need to be aware that at transition from one development phase to the next the alliance needs of the company shift. Hence, restructuring of the alliance portfolio is necessary.

In our sample, one of the companies seemed to try to jump over one of the stages with big effort but failed. The stages in the model build on each other, which gives the model an inherent logic that makes such leaps difficult. Managers must consider the inherent dynamics of networks (or the lack of these). If the attempt to jump phases leads to a significant mismatch between the firm's strategy, its capabilities and its alliance network, major problems have to be expected. We do not claim that it is impossible to be a fast network developer but we highlight the fact that such fast development needs to be managed very carefully.

At last, managers should recognize that some alliances (e.g., for basic research) might become less necessary and effective in later phases and bind resources that are needed somewhere else. In such cases, managers should consider to terminate the alliances. In general, it is important that there is an alignment between what the firm wants and what the network offers.

Appendix

Table 1: Alliances and business relations directed towards technology

Function of partner	Companies	Research institutes
Know-how supply	Sometimes pure licensing from partner (e.g., pharmaceutical drugs)	Funded joint research projects to develop new products and to improve the technology of existing products R&D projects of institute paid by focal company Non-project based R&D cooperation to tap strategic know-how of the institute License from institute to market its developments Some joint ventures Renting employees of institute Non-project based cooperation based on personal contacts established during several joint projects*
Product supply	Outsourcing of production to supplier (base chemicals, single mechanical parts, software etc.) excluding the core know-how (often too special, avoids drain of strategic know-how) Joint development financed by each partner itself, later supplier makes money with new parts Development of supplier paid by focal firm Continuous collaboration to improve supplied parts, often own innovation drive of supplier is mandatory*	Usage of infrastructure owned by the institute (e.g., high-technology production lines, IT) Institute produces and sells its developments in small numbers Institute carries out informal analyses to control product and process quality of focal company*
Comple-mentary technology	Joint development of systems (usually one partner will later take the lead as system integrator, sometimes joint offers to customers) Joint research projects	(none)
Competitor	(none)	(none)

*Business relationship without alliance character

Table 2: Alliances and business relations directed towards the market

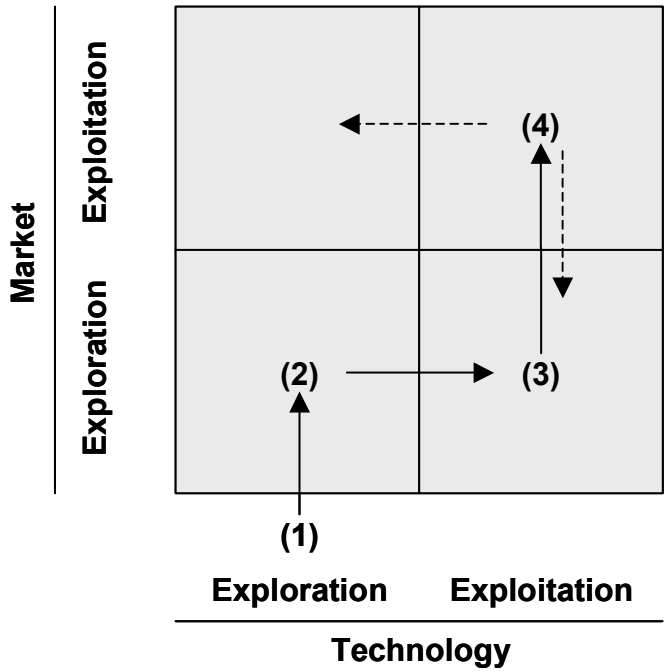
Function of partner	Companies	Research institutes
Comple-mentary technology	Partner refers its customers to focal company	(none)
Competitor	(none)	(none)
Marketing and sales	Contracts with partnering wholesalers to cover other countries, non-strategic customers, etc. Cross partnerships for selling each others products	Non-project based cooperation with selected institutes using their high reputation in certain industry sectors for establishing standards Personal marketing efforts of institute professors to support spin-offs of own institute*
Customer	Focal company adapts product to particular customer needs Contract-based developments of focal company for single customers Alliances with dominant customers to establish products in certain industry sectors Sometimes collaborative product development with major key accounts, focal company gives them superior status and grants exclusivity in some cases Joint developments with system integrators as customers Focal company provides support for usage/application of product to customers*	Institute buys products (e.g., special instruments)* Institute provides technical feedback and proposals for improvements*

*Business relationship without alliance character

Table 3: Actual business activities in the different stages

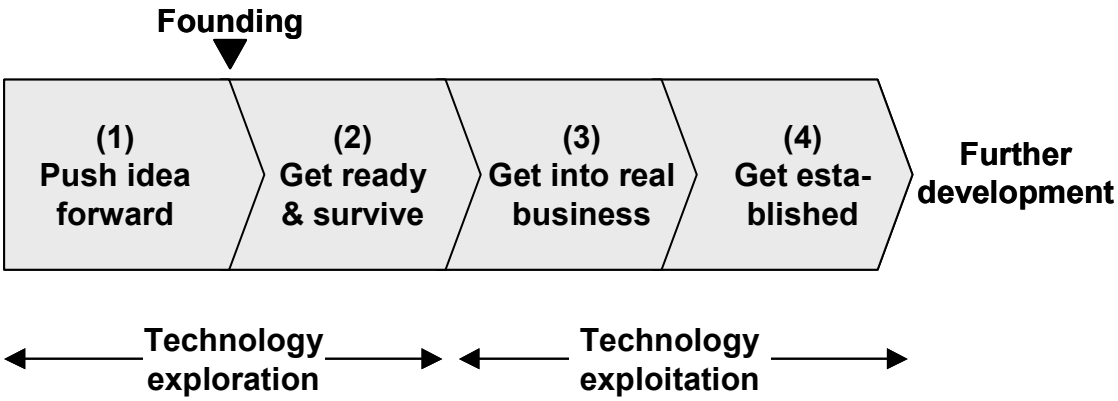
Stage	Definition	Business activities (empirical result)
1	Technology exploration only	Before foundation of the companies, research leads to an innovative product idea, and usually there are no sales so far.
2	Technology and market exploration	After foundation, companies start to improve the basic technological concept (e.g., by building and refining prototypes), and ensure medium-scale production. At the same time, most of the companies get to know the first customers by rather opportunistic than planned sales.
3	Technology exploitation and market exploration	Later, the companies begin with technology exploitation and modify their products to target particular customer groups and serve their needs better. At the same time, companies push their products into the market by focus search or creating needs. They build and expand their customer base by using a planned market approach.
4	Technology and market exploitation	Companies start the exploitation of the market. The deepening relations to customers allow concrete problem solving. Main goals of the companies become to satisfy the existing customers and to establish a reputation and brand name. Some companies explore additional markets. The core technology is continuously updated to stay at the top frontier of technological development, and usually the product line gets extended.
Further development	All activities after stage 4	Some companies seem to become specialists and stay at stage 4 for long times. Other companies get into exploration mode again and explore again new markets because their existing markets are shrinking or fundamentally new technologies in order to add innovative products to their offer and to grow faster.

Figure 1: Exploration and exploitation framework



Note: Numbers in brackets denote development stages.

Figure 2: Stage model



Formation of technology alliances:

- Research institutes and other companies for general research
- Suppliers for special single parts

- Research institutes for additional know-how and quality analysis
- Suppliers for upscaling production and improving parts

- (none)

- Research institutes and com-panies to acquire best-practice know-how (sometimes acquisitions)

Market exploration **Market exploitation**

Formation of market alliances:

- (none)

- Institutes and high-tech com-panies as customers or system integrators
- Wholesalers and distribu-tors for sales

- Customers and institutes for application know-how
- Market leaders and well-known institutes for setting standards

- A few most important customers for special joint development (often offering exclusivity)

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