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Research Paper

Technology transfer by new ventures within the chemical and pharmaceutical industry

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The role of new ventures for technology transfer from universities and research institutions to companies and between companies focused on the chemical and pharmaceutical industry are discussed in this article. Different aspects of this technology transfer approach like the maturity of the technology, the acquisition of additional resources and the technology transfer results have been analysed based on case studies from the chemical and pharmaceutical industry in Germany and Switzerland. Especially established industries like the chemical and pharmaceutical industry rely on effective and efficient technology transfer to maintain their global competitiveness. Academic spin-offs can help to transfer technologies to the industry if further research and development work is out of scope of the academic institutions. Corporate spin-outs are an alternative to closing operations should these no longer fit into the parent organization. For technology transfer, both spin-offs and spin-outs can be integrated into a new parent company or work as service provider. Internal start-ups were identified as a new approach for company internal technology transfer from research departments to business units focused on commercial operations to overcome innovation barriers within companies.

1 Introduction

The European Union has been confronted with a phenomenon called knowledge paradox (Pavitt 2000). The high quality of research at universities and research institutions has not been translated into commercial applications in a sufficient way. Licensing is the established way to transfer technology from universities and research institutions to the commercial sector. But licensing is only applicable when technologies can be protected by patents (Hearn 1981). If the technology is not mature enough to establish strong IP rights, the commercialization of the technology is difficult. Besides licensing, academic spin-offs from universities and research institutions can be used for technology transfer (Franklin et al. 2001). Despite the fact that normally licensing is short-term financially more attractive, the ownership of equity in spin-offs may increase the potential up-side gain and is an attractive option to universities and research institutions. Taking equity in a spin-out company can produce a greater average return in the long run compared to licensing business (Bray and Lee 2000).

This paper investigates the creation of new ventures like spin-offs and spin-outs as a method for technology transfer from universities and research institutions to companies and between companies. Additionally, the approach of internal start-ups for company internal technology transfer, which is not yet described in the scientific literature, was identified during our research. The paper specifically seeks to address the following research questions.

- **RQ1?** How was the maturity of the technologies increased within the new ventures?
- **RQ2?** How were additional resources acquired by the new ventures?
- **RQ3?** Which technology transfer results were achieved by the new ventures?

The chemical and pharmaceutical sectors as mature industries were selected as they rely on effective and efficient technology transfer to main-

tain their global competitiveness. They are globally one of the largest manufacturing industries with strong impact on other industries. The regional focus was on the two countries Germany and Switzerland with a globally very strong chemical and pharmaceutical industry. This regional focus was chosen to have the same general cultural background which makes the analysis of the organizational, managerial, financial and cultural similarities and dissimilarities more reliable.

Section 2 of this paper provides the theoretical background according to academic spin-offs and corporate spin-outs. The methodology is described in section 3, the results and discussions are shown in section 4 and the implications and conclusions in section 5.

2 Theoretical background

2.1 Academic spin-offs

Technology transfer through the creation of academic spin-offs is important especially in high-tech areas (Shane 2002; Heirman and Clarysse 2004; Stam et al. 2009). There has been a substantial increase in the number of academic spin-offs created in Europe (Wright et al. 2004; Moray and Clarysse 2005; Clarysse et al. 2007). This is based on a change in government policies that encourage universities and research institutions to commercialize their research results. Besides teaching and research, it is a mission for universities and research institutions to support economic and social development by commercializing the output of basic research through technology transfer (Etzkowitz et al. 2000; Etzkowitz 2003).

In the United States, the Bayh-Dole Act has granted the institutions, in which research is conducted using governmental funds, ownership of their research outcome in order to support their commercial application (European Commission 2003; Grimaldi et al. 2011). In consequence, the enactment of the Bayh-Dole Act in 1980, accompanied by other measures (Popp Berman 2008), had been substantially enhanced the commercialization of technologies developed at universities and research institutions. In contrast in Europe the legislative counterparts were lagging behind for about 20 years (Grimpe and Fier 2010) and the policy approaches are very heterogeneous (Mustar et al. 2008; Wright et al. 2008). Following the United States model, several European countries adopted comparable policies aimed at encouraging a more active role for academic institutions in technology transfer (Grimaldi et al. 2011) on national level, while other countries have acted in exactly the opposite way. In line with Bayh-Dole, Germany made an equivalent step through the abolishment of the so-called professors' privilege in 2002, which had granted the scientists the right to claim ownership of the research outcome of their scientific work, even if the underlying research was funded by public money designated to the university. In the same year, however, Italy, has newly introduced the professors' privilege. In contrast to these regulations on national level, in other European countries such as the United Kingdom each university has defined its own rules in respect of the ownership of the research results (Czarnitzki et al. 2009).

Founding a start-up out of a university or research institution is a special challenge for entrepreneurs. Normally academic researchers do not have the knowledge, expertise or experience to commercialize their research results (Litan and Mitchell 2007). Therefore, many universities and research institutions have implemented technology transfer offices (TTOs), entrepreneurship centers and incubators (Goldfarb and Henrekson 2003; Bercovitz and Feldmann 2006; Rasmussen et al. 2006). These TTOs recognise start-ups as an interesting method of technology transfer and thus help scientists in their entrepreneurial efforts (Markman et al. 2005; Meyer 2006). It is important that universities and research institutions have clear strategies towards spin-off activities (Lockett et al. 2003). This includes the build-up of expertise and networks as well as the allocation of sufficient resources to realize the strategy in a professional way.

2.2 Corporate spin-outs

Whereas the term R&D spin-off stands for a new company based on the findings of members of a research group from academia, the common definition of spin-out is when a part (department, business unit division or even a project team) of a company or organization becomes an independent business (De Cleyn and Braet 2009; Mustar et al. 2006). But the two terms are not always used unambiguously, as sometimes the term corporate spin-off is used for a small company which has been split-off from a larger, parent organization. Following a merger or simply complementing a strategic realignment on core areas, spin-outs provide an option to leverage assets of low strategic importance, or underexploited assets in their parent companies. The spin-out company takes personnel, assets, IP, technology, and existing products from the parent organization. In many cases the management team of the new company originates from the same parent organization. A corporate spin-out may initially face fewer difficulties than an academic spin-off, because companies, as par-

ent organisations, could assist a start-up company better than universities and research institutions (Jagersma and van Gorp 2003). The parent company provides the necessary assets and IP and an external investor finances the liquidity of the new start-up.

In the case of redundant capacities or non-core activities (e.g. after a merger of two companies), a spin-out can be used to reduce capacities and costs as an alternative to closing or selling the unit (Parhankangas and Arenius 2003; Bergh and Lim 2008). The reduction of capital requirements and risk, if R&D projects are not in the strategic focus of a company, can be another reason (Chemmanur and Yan 2004). As many areas of the R&D process chain can be outsourced and covered by external service providers, they will play a more important role in industrial R&D. Service oriented spin-offs and spin-outs contribute towards this, as these provide highly specialized services. Therefore, spin-outs can also be used as a method to make R&D more flexible for increased effectiveness and efficiency (Krishnaswami and Subramaniam 1999).

3 Methodology

3.1 Research approach and quality

The research method used in this study was the case study approach, due to its many benefits. It represents a combination of learning just by watching (Helper 2000) with the main advantage being that the object of study is studied in real life context (Yin 1981). Flyvberg (2006) states that "the case study produces the type of context dependent knowledge that research on learning shows to be necessary to allow people to develop from rule-based beginners to virtuoso-experts".

In contrast to the single case study approach, which aims at falsifying theoretical insights or to provide new insights in unexplored phenomena (Yin 2003; Yin 2006), many authors consider results from multiple case studies as more convincing, trustworthy, and robust (Eisenhardt 1989; Yin 2006). Therefore, the multiple case study approach was applied in this research, which compares cases and highlights resulting insights through similarities and dissimilarities between them. The cases were selected on an objective of maximum variation, thus enabling us to obtain information on the significance of various circumstances for the identified case studies (Flyvbjerg 2006).

In order to gain a better understanding of actual events and to avoid the influence of personal views and theoretical perspectives on the data collection, interviews based on a narrative approach (Polkinghorne 1988; Czarniawska 1998; Pentland 1999) were conducted, whereby the interviewees described their role with little interruption from the interviewer. To develop the case studies, semi-structured interviews were used as well as the inclusion of various sources of qualitative and quantitative data, such as document and literature analysis and observations (Yin 2006). As suggested by Eisenhart (1989), data triangulation was used to help achieve a more holistic view of the case studies. With the different rounds of interviews and the combination of the various sources of information collected over a long period of time, an in-depth description of the different technology transfer approaches was obtained.

Quality assurance is important when conducting explorative research applying a multiple case study approach and analysing qualitative data research (Bortz and Döring 2005; Yin 2006; Corbin and Strauss 2008; Lamnek 2008). As Yin (2006) stated, reliability of qualitative research can only be achieved by a structured way of proceeding and by exactly documenting the research process and its results. Since there can be no validity without reliability, a demonstration of validity is sufficient to establish reliability, so that reliability is a consequence of the validity in a study (Patton 2002).

3.2 Data collection and analysis

Between 2004 and 2006, literature research on academic spin-offs, corporate spin-outs and their application for technology transfer in both academic and practitioner oriented journals as well as the internet was carried out. With the information collected, a database was obtained with interesting examples from two industries (chemicals and pharmaceuticals) and two technologies (biotechnology and nanotechnology) in Germany and Switzerland. From this database, 15 academic spin-offs, 12 corporate spin-outs, 16 universities and research institutions as well as 6 TTOs, 25 companies and 23 venture capitalists (VCs) including corporate VCs were selected based on their fit to the research scope and their interest in and availability for an interview. Narrative interviews were conducted with them between 2006 and 2008. One-on-one interviews of approximately one hour were conducted in an unstructured, open-end way without any formal questionnaire. Prior to the interview, the interviewer collected in-depth information on the company or institution through various public sources (e.g. databases, website, press releases) to enable an efficient conduct of the interviews.

The selection of case studies from the interviews for the research was based on an objective of maximum variation to cover the whole range of

cases, the potential to obtain appropriate answers, and the willingness to further participate in this study. Table 1 shows details of the 12 selected case studies from Germany and Switzerland: 5 case studies each for academic spin-offs and corporate spin-outs and 2 for internal start-ups (see appendix). The same interviewer conducted again one-on-one interviews with the 12 selected case studies between 2008 and 2009. This time semi-structured interviews were used in order to develop these 12 case studies, whereby a reference set of questions was developed as a guideline for the interview, which allowed room for spontaneous answers. The questions were structured around different topical groups, like basic data regarding the case studies (parent institution and technology owner, involved parties), background for creating a new venture (reasons and strategy, relevance of technology transfer aspects), realization of the a new venture (conceptual design, engagement of investors, spin-off/spin-out process) and the results of these activities (development of the new venture, achievement of technology transfer goals).

The results of these semi-structured interviews as well as the narrative interviews were analysed and compared regarding the research questions. Additional secondary data was collected from the interviewees and through internet research for all the case studies. To identify relevant scientific literature and to update the case studies, a final literature research was conducted in the first half of 2011.

4 Results and discussions

4.1 Maturity of the technology

Within all analysed academic spin-offs the maturity of the technology was not sufficient to directly commercialize the technology. Table 2a shows the case specific mix of the identified aspects causing the need for further development of the technology and Table 2b case study specific details (see appendix).

All case studies had proof-of-concept only at laboratory scale with missing upscaling know-how to realize technical scale. Other aspects are no cost effective production processes, so that the new products cannot be produced on a cost competitive level, low relevance for industrial applications or insufficient performance. If there is no customer feedback, due to a missing prototype or access to customers, the customer acceptance of the new products is unclear. Further R&D is also necessary, if the new products have no competitive advantage in the eyes of the customers. No validation for commercial use and no fulfilled regulatory hurdles are also reasons for additional R&D activities. Case study B had a production technology for new nanomaterials only in laboratory scale without any expertise and experience for upscaling into the technical scale. The further R&D work focused on the upscaling of the laboratory process into a technical feasible process and development of formulations for a customer from the consumer industry. The result was a cost effective production process for a broad range of nanomaterials and formulations which could be directly used by the customer.

The identified kinds of further R&D work showed typical aspects. Equipment development means developing hardware and software for the cost efficient implementation of a new technology in the industry. Of importance is also upscaling of production processes through process development and the development of a cost effective production process. The improvement of performance enables the implementation in the industry. Scientific understanding of key aspects enables to improve the performance and to fulfil regulatory requirements. Other aspects are the development of industrial applications (e.g. implementation of products and technologies in the industry), the development of special grades or formulations for technical applications and the development of marketable products or service offerings. All these aspects were relevant for case study D. The development of industrial relevant strains for the proof of the genetic tools to modify microorganisms for the production of biofuels and bio-based chemicals was the critical step to get an industrial relevant strain with sufficient performance (yield, robustness) to produce ethanol in world scale production plants. Also within case study E, the improvement of biocatalysts in selected technical processes together with industrial partners was necessary to develop biocatalytic systems used in industrial applications with high performance and lower production costs compared to established chemical systems.

Typical results of the further R&D activities could be identified. An example for the importance of equipment for industrial applications and of providing of fee-for-service work is case study A. The high throughput experimentation technology had at the university only proof-of-concept in laboratory scale and high operational costs in industrial applications due to low automation of the process. The development of high throughput experimentation equipment enabled the spin-off to provide fee-for-service work for industrial customers and to sell the equipment to these customers. Other results were cost effective production processes for larger quantities, formulations for customer specific solutions and validated systems with cer-

tification.

The aspects describing the need for further R&D work in the case of corporate spin-outs and internal start-ups were rather similar to academic spin-offs, i.e. there is no clear difference between the three groups. Also, the kinds and the results of further R&D work were very similar in the three groups of case studies. Case study H shows that the corporate spin-out enabled the further development of selected technologies and correlated services based on scientific expertise. The result was a worldwide well-known provider of special pharma development services with strong teams consisting of scientists and marketing and sales experts. The described aspects were also relevant for case study K. The new nanomaterials from the laboratory were not really relevant for the industry as the particle size and the application properties were not suitable for industrial processes. Further R&D work of the internal start-up together with the business units of the parent company solved these problems. Another result was the cost effective production process for a broad range of nanomaterials and formulations which could be directly used by the consumer company in their products.

4.2 Acquisition of additional resources

Clear differences can be seen in the three groups, academic spin-offs, corporate spin-outs and internal start-ups, with regard to the acquisition of additional resources to realize the additional R&D work. Table 3a shows the identified aspects and table 3b the case study specific details (see Appendix).

Academic spin-offs need additional resources because there is no academic interest in further R&D, the topics are out of scope of universities or there are not enough resources at universities. Financing of additional resources is made by industrial partners, VC and corporate VC as well as strategic investors. Case study E showed the need for additional resources at universities in areas which are out of scope and not interesting from an academic point of view. The cost intensive further R&D work to develop industrial relevant biocatalysts could not be financed by the universities as technology owner and was financed by VC. Case study D is an example for a technology development within the academic scope of the university but where the necessary resources were not available at the university and a strategic investor financed these resources. Case studies A, B and C were examples of an investment of industrial partners who worked along with their investment also operationally close with the academic spin-off. The main reasons for investment are large market potentials and the opportunity of a trade sale or initial public offering (IPO) attracting strategic and VC investors.

For more and more non-core R&D projects in industrial companies there are not enough company internal resources (capital, management capacity) available resulting in the divestment of these projects. The need for additional resources for corporate spin-outs is caused by this divestment process from the parent company. In the case of corporate spin-out J, the parent organization spun-out parts of the clinical research department as an alternative to closing down operations. Another possible reason to realize a spin-out is the isolation of high risk projects, in order to protect the parent company from these risks, like in the case of case study G. The divestment of a drug development project by the parent company was the result of company internal problems during the development process which increased the further development risk significantly. These spin-outs enable companies to concentrate on their core activities, without having to abandon new products coming from these projects. As in the case of academic spin-offs, the additional resources are financed by industrial partners, VC including corporate VC and strategic investors. Reasons for the investment are, besides the opportunity of a trade sale or IPO, the realization of value creation potentials and to provide flexible services for the parent company. Case study H was the divestment of a pharma service department after the merger of two pharma companies. The spin-out was realized by the corporate VC department of the parent company together with strategic investors with pharma experience. A major intension of the parent company was, despite the reduction in headcount, to further use parts of the services which were no longer available inhouse on a flexible basis. Case study J was the divestment of parts of the clinical research department of a pharma company after the merger with another pharma company. Aim was the creation of a leading clinical research organization to further use these services.

The situation of internal start-ups is rather different compared to academic spin-offs and corporate spin-outs. The need for additional resources is due to the fact that the R&D work is too risky and the market proof-of-concept is not yet shown. As there are not enough resources in the business unit, the financing gap is closed by corporate R&D budgets. Within the case studies K and L, the relevant business units within a chemical company were not willing to finance the R&D work due to low success probability. The additional investment by corporate R&D budgets was made because there was the possibility to bring innovative products with over average profitability onto the market to strengthen the existing business. Aim from a cor-

porate point of view was increased innovativeness and the realization of growth option which could not be realized with only the resources of the business unit.

4.3 Technology transfer results

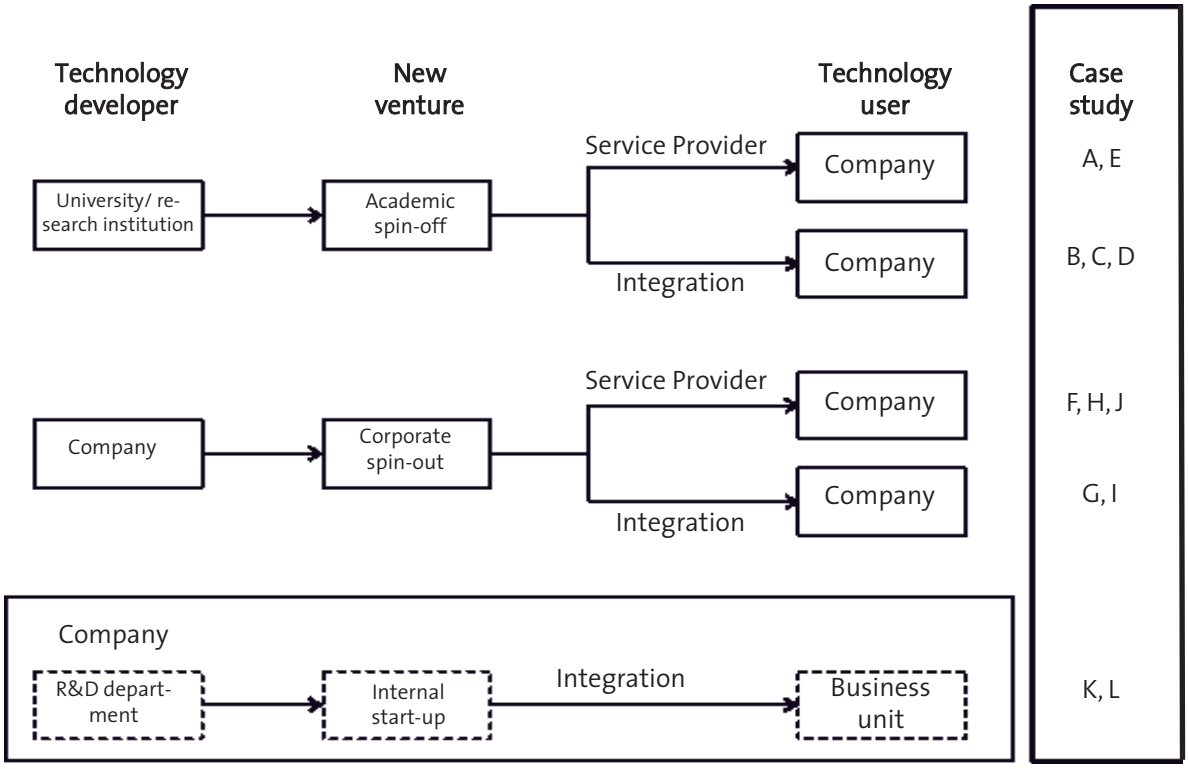
The analysis of the technology transfer results showed some similarities and dissimilarities between the three groups. Table 4a shows the analysis regarding technology transfer goal, technology transfer impact and technology transfer success and Table 4b some case study specific details (see Appendix).

In the case of academic spin-offs, the goal is the technology transfer from universities to industrial partners. In all analysed cases studies, the technology transfer was successful: there were some market introductions of new products and, in some cases, the integration of the spin-off into an industrial company. For example, in case study D, there was a joint development of a new product and the later acquisition of the academic spin-off by the industrial partner. This enabled the global market launch of a new product for ethanol by combining the production and marketing/sales capabilities of the buying company and the technologies of the acquired spin-off. This is an example of the transfer of a technology from a university to a company via the purchase of the spin-off company. Case study A shows that the technology transfer is not only done through the sale of the spin-off but also by acting as a service provider for industrial customers.

Corporate spin-outs realize technology transfer from the parent company as a new legal entity to further develop the technology as an alternative to closing the operations. As in the case of academic spin-offs, the technology transfer can be realized by the trade sale to a new owner or by acting as a service provider. The case studies showed in some cases the market introduction of new products and in other cases the integration into a new company. For example, case studies H and J executed the transfer of the operations into a new legal entity with the aim to further develop and commercialize the services offerings. The result was independent companies with cost competitive services which were widely used by the former parent companies as well as other customers from the pharmaceutical industry.

Internal start-ups, like case studies K and L, show

Figure 1 Technology transfer by academic spin-offs, corporate spin-outs and internal start-ups.



the technology transfer from R&D departments into a commercial business unit. Result was in both cases the integration of (parts of) the internal start-up into a business unit of the parent company in combination with the introduction of new products into the market.

5 Implications and conclusions

The analysis of the case studies confirmed that the creation of new ventures could be used for technology transfer from university, research institutions and companies as technology developers to companies as technology users (figure 1). In all case studies the maturity of the technology was not sufficient to directly commercialize the technology. Necessary was the further development of the technology to a stage interesting for established companies which are looking to offer concrete products or services. The technical proof-of-concept has normally to be done before investments in production, marketing and sales are made. The need for further R&D work is a central element of using new ventures for technology transfer combined with the fact that the parent organization (universities, research institutions and companies) is not able or willing to finance this additional R&D work.

Academic spin-offs can especially help to transfer technologies to the industry if they are out of scope of the academic institutions or there is no academic interest in the work. Corporate spin-outs can be used for technology transfer as a good alternative to closing R&D operations if they no longer fit into the parent organization and the technology is not mature enough to sell it directly. Both spin-offs and spin-outs have to acquire additional resources from external partners like financial investors or industrial co-operation partners to increase the maturity of the technology. The technology transfer back to industrial companies can work in two ways: the new ventures can work as service provider as an independent company or be sold and integrated into a new company.

The principle of company internal start-ups, which is using many elements of academic spin-offs and corporate spin-outs, can help to improve technology transfer from research labs of R&D departments to commercial business units within the same company. The internal start-up will be integrated into an operational business unit if the technological and market proof-of-concept is shown. Corporate spin-outs and internal start-ups can overcome innovation barriers like bureaucratic thinking, fear of cannibalism or the well-known 'not invented here' syndrome which are normally found within companies.

The new ventures enable the opportunity to combine scientific expertise with business expertise of external managers or entrepreneurs. They can more easily pick up external impulses and serve as a mechanism to explore revolutionary ideas in a setting apart from mainstream business. For example, competencies from other companies or top-class scientists from universities and research institutions can be engaged to form excellent teams.

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Appendix (see the following tables)

Table 1 Characterization of the case studies.

Type	Case Study	Parent institution and starting point	Year and reason for founding a new venture	Import realization steps and current status
Academic spin-offs	A	University in Germany: High throughput experimentation technology with proof-of-concept in the laboratory and potential for chemical companies	1999 / Additional financial resources for the development of the technology to a stage interesting for established companies	VC financing (including corporate VC of a chemical company) with industry co-operations from the beginning / Chemical company as majority shareholder
	B	University in Germany: Production technology in laboratory scale for new nanomaterials with potential applications in consumer products	2000 / Additional financial and human resources for the development and testing of products for the consumer market	Spin-off supported by a consumer company providing money and management capacity / Integration into consumer company
	C	University in Germany: Specialized and non validated laboratory testing system to develop and study new active ingredients for cosmetics without animal tests	2001 / Additional financial and human resources to use the system in a broad set of validated applications in the cosmetics industry	Finding an industry partner from the cosmetics industry to support the spin-off process / Integration into cosmetics company
	D	University in Germany: Genetic tools to modify microorganisms for the production of biofuels and first laboratory strains for ethanol production	2007 / Acquisition of strategic investors for further funding of the technology development (e.g. the development of industrial relevant strains)	R&D work at the university financed by the investor and co-development of a first product together with an industry partner / Trade sale to industrial partner
	E	University in Germany: Molecular biological tools to modify microorganisms in the laboratory to develop cost effective biocatalysts for new applications	2008 / Further development of the biocatalysis technology from laboratory scale to technical scale in a broad range of applications	VC financed development with industrial partners to show the technical proof-of-concept / Independent company
Corporate spin-outs	F	Pharma company in Switzerland: Trade sale of a pharma company's liquid crystal business, without the R&D department, to another company	1995 / Spin-off of the R&D department to bring in VC investors for further funding of the technology development	Development of the R&D department into a fully integrated company from raw material sourcing to marketing and sales / Independent company
	G	Pharma company in Switzerland: Desinvestment of a drug development project with a failed drug candidate of a pharma company	1998 / Possibility for further funding of the drug development and to acquire other drug candidates (especially a cost competitive production route)	Building-up an own pipeline of drug candidates through in-licensing and development of own projects / Integration into former parent company
	H	Pharma company in Switzerland: Reduction of overcapacities of a broad range of pharma development services after the merger of two pharma companies	1999 / Possibility to deliver the partly, very specialized services with high hardware costs to a broader group of customers from the pharma industry	Restructuring of the operations to provide a cost competitive range of services needed by the pharma industry / Independent company
	I	Strategic decision of a chemical company to divest parts of the non-core pharma operations	2001 / Acquisition of VC investors for further funding of the technology development	Restructuring of the operations including sale of parts to other companies and development of a pipeline of drug candidates / Merger with another company
	J	Pharma company in Germany: Reduction of the overcapacities within the clinical research operations after the merger of two pharma companies	2002 / Possibility to deliver the partly, very specialized clinical research services to a broader group of pharma companies	Focusing of the service offerings to target special niche markets and restructuring of the company's internal resources / Independent company
Internal start-ups	K	Chemical company in Germany: Laboratory scale production technology for nanomaterials for a broad range of applications	2003 / Company internal cannabilization effects with established products	Building-up of an own semi technical production facility to deliver larger quantities of the nanomaterials to customers / Integration into business unit
	L	Chemical company in Germany: Technology to produce very specific catalysts for organic chemical synthesis	2004 / Low acceptance of the new catalytic approach within the established R&D organization of the chemical company	Developing of a broad range of catalysts and building-up of a marketing and sales team / Integration into business unit

Table 2a Maturity of the technology (overview).

	Case study											
	Academic spin-offs					Corporate spin-outs					Internal start-ups	
	A	B	C	D	E	F	G	H	I	J	K	L
Need for further development												
Only proof-of-concept at laboratory scale	X	X	X	X	X	X	X	X	X	X	X	X
No upscaling into technical scale	X	X	X	X	X	X	X	X	X	X	X	X
No cost effective production process	X	X		X	X	X	X	X	X	X	X	X
Low relevance for industrial applications	X	X	X	X	X	X		X		X	X	X
Not sufficient performance	X	X	X	X	X	X		X		X	X	X
No customer feedback	X	X	X	X	X	X			X		X	X
No competitive advantage		X	X	X	X	X		X	X	X	X	X
No validation for commercial use	X	X	X	X	X	X	X	X	X	X	X	X
Not fulfilled regulatory hurdles			X				X		X	X		
Kind of further development												
Equipment development	X			X		X		X			X	X
Process development/upscaling	X	X		X	X	X	X	X	X	X	X	X
Development of a cost effective production process	X	X		X	X	X	X	X	X	X	X	X
Scientific understanding of key aspects	X	X	X	X	X	X	X	X	X	X	X	X
Improvement of performance	X	X	X	X	X	X	X	X	X	X	X	X
Development of marketable products/services	X	X	X	X	X	X	X	X	X	X	X	X
Usage in industrial applications	X	X	X	X	X	X	X	X	X	X	X	X
Result of further development												
Equipment for industrial applications	X			X		X		X			X	X
Providing of fee-for-service work	X		X	X	X	X		X		X	X	X
Cost effective production process for larger quantities	X	X		X	X	X	X	X	X	X	X	X
Performance high enough for industry	X	X	X	X	X	X	X	X	X	X	X	X
Customer specific products/services	X	X	X	X	X	X	X	X	X	X	X	X
Validated systems with certification	X		X				X	X	X	X		X

Table 2b Maturity of the technology (case study specific details).

Type	Case Study	Why was the need for further development of the technology?	What kind of further development of the technology was necessary?	What was the result of the further development work?
Academic spin-offs	A	High throughput experimentation technology only with proof-of-concept in the laboratory scale at the university and high operational costs due to low automatization	Automatization of the high throughput approach including the development of the necessary equipment to fulfil the requirements of industrial customers	High throughput experimentation equipment which was used for fee-for-service work for customers and sale of the equipment to these customers
	B	Production technology for new nanomaterials only in laboratory scale without any expertise and experience for upscaling into the technical scale	Upscaling of the laboratory process into a technical feasible process and development of formulations for a customer from the consumer industry	Cost effective production process for a broad range of nanomaterials and formulations which could be directly used by the consumer company in their products
	C	Specialized laboratory testing system without any validation to use it for regulatory purposes in the cosmetics industry	Scientific understanding of the test systems for validation purpose and for usage in a broader scope of potential applications	Validated test system accepted by the regulatory authorities in the cosmetics industry which could be used in skin care projects as test system
	D	Only first laboratory strains for ethanol production with low relevance for industrial application and no robust industrial strains	Development of industrial relevant strains for the proof of the genetic tools to modify microorganisms for the production of biofuels and biobased chemicals	Industrial relevant strain with sufficient performance (yield, robustness) to produce ethanol in world scale production plants
	E	First reactions with new biocatalysts in the laboratory with insufficient activity of the catalysts	Improvement of biocatalyst activities in selected reactions and usage in technical processes together with industrial partners	Different biocatalytic systems used in industrial applications with high performance and lower production costs compared to established systems
Corporate spin-outs	F	Broad range of liquid crystal research projects with the need to focus and develop them to an industrial relevant stage	Introduction of a market oriented project management system, selection and development of the most promising projects towards marketable products	Broad range of products for the security market based on liquid crystals and promising R&D project pipeline
	G	Drug candidate in clinical phase I and other clinical tests to obtain permission to enter the market and cost effective production process	Clinical studies in phase II and III, submission of all necessary data to the regulatory authorities and development of a cost effective production process	Successful pass of the clinical phase III and implementation of a cost effective production process
	H	Broad range of pharma development services without competitive advantage compared to other service providers	Further development of selected technologies and correlated services based on scientific expertise to be global market leader in these service segments	Provider of special pharma development services with strong teams consisting of scientists and marketing and sales experts
	I	Development of drug candidates to bring own products to the market	Further development of the early stage drug candidates to marketable products	Drug candidates in later stages and also products on the market
	J	Very specilized clinical research services without the ability to handle the generated data in the drug development process	Development of the services towards complete service offerings based on high scientific standards including data handling	Cost effective provider of special pharma development services with strong data handling ability
Internal start-ups	K	Only laboratory scale and not application specific production technology for nanomaterials	Development of applications for the nanomaterials together with a cost effective technical scale production process	Broad range of nanomaterials provided to different company internal and external customers
	L	Only laboratory scale production technology for specific catalysts for organic chemical synthesis	Development of a broad range of synthesis routes for the catalysts together with customers	Broad range of catalysts mainly to company external customers in the chemicals and pharma industry

Table 3a Acquisition of additional resources (overview).

	Case study											
	Academic spin-offs					Corporate spin-outs					Internal start-ups	
	A	B	C	D	E	F	G	H	I	J	K	L
Need for additional resources												
No academic interest	X	X	X		X							
Out of scope for universities	X	X	X		X							
Not enough resources at universities	X	X	x	X	X							
Divestment of non-core operations						X	X	X	X	X		
Spin-out as alternative to closing operations						X	X	X	X	X	X	X
Not enough resources in the business units											X	X
Development work too risky						X	X	X	X	X	X	X
Market proof-of-concept not yet shown						X	X		X		X	X
Financing of additional resources												
Industrial partners	X	X	X						X		X	X
VC (including corporate VC)	X				X		X	X		X		
Strategic investors				X		X						
Corporate R&D department											X	X
Reason for investment												
Large market potentials	X	X		X	X	X	X		X	X	X	X
Opportunity of a trade sale or IPO	X			X	X	X	X			X		
Realization of value creation potentials								X		X		
Flexible services for the parent company								X		X		
Increased innovativeness of the parent company								X			X	X
Realization of growth option for the parent company											X	X

Table 3b Acquisition if additional resources (case study specific details).

Type	Case Study	Why were additional resources necessary?	Who financed the additional resources?	Why was this investment made?
Academic spin-offs	A	Equipment development at the university not possible (out of scope and no resources available)	R&D contracts with industrial partner interested in the technology and later VC (including corporate VC of the industrial partner)	Interest of the industrial partner in this technology and especially the equipment to implement the technology inhouse
	B	Cost intensive upscaling of the nanomaterials production process out of scope at the university	Money and management capacity from a consumer products company, as preferred commercial partner, based on an exclusive agreement	Nanomaterials for the improvement of existing products as one of the strategic growth projects within the consumer products company
	C	No academic interest in developing and validating the test system	Money and management capacity from a cosmetics company, as preferred R&D and commercial partner	Test system as an important step towards developing cosmetics without animal tests due to the public's critical view regarding animal tests
	D	Development of an industrial strain within the academic scope but necessary resources (scientists and equipment) not available at the university	Strategic investment of a company from the renewable energy sector to further develop the technology at the university on the basis of research contracts	Large market potential and possible synergy effects to the core business of the strategic investor
	E	No academic interest in developing industrial relevant biocatalysts due to restricted resources at the university	Investment from two VCs for the build-up of own laboratories for the development and commercialization of new biocatalysts	Market potential of the biocatalysts within the area of industrially relevant catalyst development
Corporate spin-outs	F	Divestment of the R&D department by the parent company due to focusing on the core business	Strategic investor with majority stake of the spin-out company based on a long term strategic engagement in this area	Trade sale to an established company or an IPO after successfully building up the business
	G	Divestment of the drug development project by the pharma company due to problems during the development process	Strategic investors with own entrepreneurial experience in the pharma industry and two VC companies with pharma focus	Market potential of the drug candidate and attractiveness of the business model to develop drugs within a virtual pharma company with external resources
	H	Divestment of the pharma service department by the parent company after the merger of two pharma companies	Corporate VC department of the parent company together with strategic investors with pharma experience	Intension of the parent company to further use parts of the services on a flexible basis (despite reducing the head count)
	I	Divestment of parts of the pharma operations of the parent company due to strategic reasons	Biopharmaceutical company in North America as long-term strategic investor	Strategy of the parent company to find a new owner for a fully integrated pharma company to earn as much money as possible with the trade sale
	J	Divestment of parts of the clinical research department by the parent company after the merger with another pharma company	Parent company has long-term strategic investor together with a VC company	Aim to create a leading clinical research organization as alternative to closing the operations due to high costs and negative image aspects
Internal start-ups	K L	Relevant business units within the chemical company not willing to finance the development work due to low success probability	Corporate R&D budget within the parent company managed by the corporate R&D department	Possibility to bring innovative products with over average profitability onto the market to strengthen the existing business

Table 4a Technology transfer results (overview).

Type	Technology transfer goal	Technology transfer impact	Technology transfer success
Academic spin-offs	Technology transfer from the university and further development to use it by industrial partners	Transfer from the university to an industrial company via a spin-off (trade sale or service provider)	Yes, because market introduction of new products and in some cases integration into an industrial company
Corporate spin-outs	Technology transfer into a new legal entity to further develop the technology as alternative to closing the operations	Transfer from the parent company to the new owners via a spin-out (trade sale or service provider)	Yes, because market introduction of new products and in some cases integration into an industrial company (as well as survival of divested entities)
Internal start-ups	Technology transfer from R&D department into a commercial business unit	Integration of (parts of) the internal start-up into a business unit of the parent company	Yes, because market introduction of new products

Table 4b Technology transfer results (case study specific details).

Type	Case Study	What was the technology transfer goal?	What was the technology transfer impact?	Was the technology transfer approach successful?
Academic spin-offs	A	Transfer of the technology from the university and further development for application by industrial companies to improve materials R&D	Chemical company as majority shareholder for preferred access to the technology	Yes, because the technology is intensively used by chemical and material companies
	B	Transfer of the technology from the university to the industrial partner to develop new nanotechnology based products	Complete integration into the consumer company after successful market introduction of the first products	Yes, because the industrial partner integrated the spin-off after developing the technology to a maturity stage which could be used by the industrial partner
	C	Transfer of the technology from the university to the industrial partner to improve and validate the testing system	Integration into the R&D department of a cosmetics company to broadly use the testing system for new product developments	Yes, because the industrial partner integrated the spin-off after developing the technology for industrial application on a broader basis
	D	Transfer of the technology from the university to the industrial partner via purchase of the spin-off company	Trade sale to the industry partner to globally launch the product for ethanol production on to the market and to develop other products	Yes, because the technology was the missing link for an industrial company to bring a new product to the market
	E	Transfer of the technology from the university to the industrial partners on the basis of co-operations	Co-operations with chemical and pharmaceutical companies to show first technical scale applications of biocatalysts	Yes, because different industrial co-operation partners use the technology in their production processes
Corporate spin-outs	F	Transfer of the liquid crystal technology into a new legal entity to further develop the technology	Independent company as technology leader in its market segments with a broad product range already introduced into the market	Yes, because a broad range of products based on the technology has been introduced into the market
	G	Transfer of the drug development project into a new legal entity to proceed the development programme	Reintegration into the former parent company after successful development of the drug candidate with external service providers	Yes, because the drug will be introduced into the market by the former and new parent company
	H	Transfer of the operations into a new legal entity to complement and further develop the services	Independent company with cost competitive service range especially for the former parent company	Yes, because the services are widely used by the former parent company as well as other customers from the pharmaceutical industry
	I	Transfer of the drug candidates and other operations into a new legal entity to further develop the drug candidates and to restructure the operations	Merger with a publicly listed biopharmaceutical company in North America	Yes, because the drug candidate projects have been further developed and one product has already been introduced into the market
	J	Transfer of the services into a new legal entity to strengthen the service offerings	Independent company with integrated services for the pharma industry	Yes, because the services are widely used by different customers from the pharmaceutical industry
Internal start-ups	K	Transfer of the technology from R&D department into a commercial business unit	Integration of the internal start-up into a business unit of the chemical company	Yes, because the chemical companies commercialized the technology by introducing new products into the market
	L			