

**Challenging conventional technology transfer: New technology from
industry to basic research to foster new business creation**

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Abstract

This study focuses on a mechanism for industrial innovation and new business creation based on the transfer of new industrial technologies to basic research in order to foster commercialization and new business development. Using data from industrial cooperation projects with CERN* and the international fundamental physics community over a period of nine years, the study demonstrates that the validation, testing and procurement by basic research of technologies developed by industry, including joint application development and pilot prototype use by the research community, promote commercialization of these technologies and satisfy multiple needs relating to new business creation. This concept of reverse technology transfer from industry to basic research is most useful toward the end of new business creation process, and is able to provide the necessary complementary resources particularly for radical new business initiatives having limited internal support.

* CERN, the European Laboratory for Particle Physics, has its headquarters in Geneva. At present, its Member States are Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, The Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom. The European Commission, India, Israel, Japan, the Russian Federation, Turkey, UNESCO and the USA have observer status.

Introduction

Commercializing new technology is challenging. Even the leading firms fail to commercialize the new technologies they have developed (Bower and Christensen, 1995; Chesbrough, 2002; *BusinessWeek*, 1993). In general, most of new product and business ideas fail, and almost half of those launched do not succeed on the marketplace (Garvin, 2004; Griffin, 1997; Kirschoff and Phillips, 1989; Porter, 1987; SAPPHO, 1971). Many promising new technologies are not commercialized because they suffer from lack of support, competences and resources (Wilson and Hlavacek, 1984; Souder, 1989; Henderson, 1993; Teece, 1986). However, if the firm does not transform its new technology into new business, an entrant company or a competitor might do it instead and result in a discontinuous change that may even cannibalize the firm on its own marketplace (Abernathy and Clark, 1985; Tushman and Anderson, 1986; Bower and Christensen, 1995). Combining these findings on the nature of new technology-based innovation with theories on technology transfer (TT) provides a great potential for fruitful new modes of basic research-industry collaboration to catalyze new technology-based industrial innovation (Hameri and Vuola, 1996; Vuola, 2004; Autio et al., 2004). Research on TT has demonstrated that there are significant innovation benefits and knowledge spillovers from industrial collaboration with large international research centers and especially with CERN (Schmied, 1977, 1982; Brendle et al., 1980; Bianchi-Streit et al., 1984; Bach et al., 1988; Autio et al., 2003). While these contributions have greatly increased our understanding of the impact of research laboratory-industry collaboration, they have not helped particularly new entrant companies or technology teams to accrue the benefits systematically for innovation and new business creation (NBC). Hameri and Vuola (1996) proposed a basic practical model for how companies could *enter* big science centers in order to investigate possibilities for cooperation and catalyze industrial innovation, and another study (Vuola, 2004; Vuola and Hameri, 2005) developed a model of *win-win cooperation* between the research center and industry, and guidelines to manage the joint cooperation over the entire project life-cycle. However, no attempts have been to develop a theoretical framework of the mechanism of industrial use of basic research for the purpose of NBC.

This paper tries to fill in this gap by studying a mechanism for industrial innovation and new business creation based on the transfer of new industrial technologies to public research in order

to foster commercialization and new business development. The focus is particularly on a project-level process of new technology and business development that is radical compared to the mainstream business and done by a relatively small venture having not yet reached breakthrough on the market place. Second, the focus is on large intergovernmental research centers conducting basic research and their possible role especially toward the end of the innovation and new business creation process. The study aims at contributing to theories on innovation and technology transfer, and at supporting new technology ventures and project managers in their attempts to commercialize new technologies and develop their businesses. The reality for venture teams is often far from ideal, lacking resources and support, and they need advice and guidelines on how to survive and prosper, even against all odds. In this paper, we thus take the venture team perspective rather than that of the corporate management or a research center. However, the study has implications also for corporate management as well as for research organizations and policy-makers, as the ‘useless’ technologies lying around on the shelf could be considered as idle capital and potentially a source of future new business, prosperity and savings.

The study addresses especially the following research questions:

- If companies supplying technology to research centers can evidently accrue multiple secondary benefits, how could new entrant technology ventures use research centers for business development purposes?
- What is the actual process of technology transfer to basic research in the context and for the purpose of industrial NBC? What are the stakeholders as well as the success and limiting factors?

An in-depth longitudinal case study was applied, studying new technology ventures cooperating with a large intergovernmental research center. Using multiple sources of evidence, including observation, participation, interviews and documents, the cases were studied on a real-time basis from 1996 to 2004. All cases represent NBC projects that radically differ from companies’ mainstream businesses and business models. The projects take place in large corporations, SMEs and start-ups alike, and cover new technologies in different technological fields and industries.

The rest of the paper proceeds as follows. The next section describes the methods and data used in the study, including also the research strategy, data collection and analysis techniques, as well as the sample of the research organization, case companies and venture projects. In the following section, a cross-case analysis and findings are presented. Then the resulting theoretical implications are elaborated against extant theories and received literature on innovation and TT, followed by managerial implications for industry managers, research organizations, and policy-makers. The paper is concluded by recapitulating findings and providing suggestions for future research.

Data and methods

A qualitative method was chosen as the best way to arrive at an encompassing view of the very processes of TT and NBC. An in-depth longitudinal case study was applied, studying five emerging technologies and new business initiatives of five venture teams in five companies, and their collaboration with CERN*, the European Laboratory for Particle Physics. The cases have been studied on a real-time basis since 1996, providing unique opportunities to gain insight into as yet incompletely documented phenomena. Multiple sources of evidence, including observation, participation, interviews and documents, have been used. Rather than starting with specific events and trying to link these to more generic actions and theories, this study aimed at following the overall NBC cases and joint collaboration over the entire period and thus tracking down the actual NBC and TT process and the key elements, success factors and boundary conditions.

Because of the *exploratory* nature of the study and the objective of generating a descriptive model of as yet incompletely documented phenomena, Glaser and Strauss's (1967) strategy for the discovery of grounded theory was adopted. In the grounded theory method, the theory is

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supposed to emerge from in-depth case studies by taking an informed look into the cases so as to determine what the cases tell us. Glaser and Strauss (1967:37) propose to the researcher "... at first, literally to ignore the literature of theory and fact on the area under study, in order to assure that the emergence of categories will not be contaminated by concepts more suited to different areas". Therefore, the cases are studied without first developing a theoretical framework. It has been argued that claiming ignorance of existing literature only disguises the biases that every researcher carries, and the body of literature the researcher knows acts as a cognitive lens shaping his or her perceptions (Strauss and Corbin, 1998). However, while this is not contested, it has no relevance to this study: first, because the author was a relatively neophyte researcher when the study started in 1996 and his knowledge of literature on innovation and TT was very limited at that time. Second, the lack of previous research at the actual focus area of this study at the time when the study started further facilitated full compliance with the original grounded theory strategy.

Data collection and analysis

Several data sources and modes of inquiry were used to explore the subject. The field data collection period lasted for nine years, with the most intense data collection occurring during 1996 to 2001, when the author stayed at CERN on an almost regular basis. During 2002 to 2004, the author regularly visited CERN, and remained in close contact with the case companies during the entire period. On average the case companies and CERN were contacted at least once a month, but often up to several times a week during the study. In the case companies, the persons involved in the study represented several organizational levels, including CEOs, CFOs, CTOs, department managers, business line managers, project and product managers, salesmen, marketing people, R&D managers, and technical personnel at corporate, department or parent company level, as well as managing directors, projects managers and other personnel of the ventures. On the CERN side, they included members of the directorate, division leaders and heads of departments, section and group leaders, project managers, purchasing officers, and technical experts and laboratory personnel. In addition, the study also involved members of the CERN Council and the Finance Committee, as well as heads, directors and researchers at two institutes conducting particle physics research at CERN, and also officers at national funding

agencies. A limited number of policy-makers at ministries of education, trade and industry in the relevant Member State were also involved.

The author attended numerous meetings that took place between CERN and the case companies at CERN and at company premises, internal meetings at the case companies, and every CERN Finance Committee meeting during a period of almost five years from 1997 to 2001, which was also the most intensive data-collection period. The internal meetings at the case companies concerned project planning, strategic planning, funding application preparation, and tendering preparation. Both before and after each CERN-company meeting, strategic and project issues were discussed with the company participants. The CERN Finance Committee is *inter alia* the decision-making body for all major purchases and technology transfer issues.

Findings reflect the observation of and participation in these meetings, and data from hundreds of emails, phone calls and faxes, as well as the resulting notes, transcripts, remarks and assumptions for initial theoretical insights and their analysis that followed the data gathering. Preliminary findings were informally discussed with a few other researchers and policy-makers, and also with the CERN director for TT, who were not directly involved in the study and the cases, but provided their time and insight. In addition, initial findings were also discussed with the case companies during the case projects, but this was found less fruitful at that stage, possibly because the theoretical findings could not yet be formulated into and communicated in the form of clear practical advice.

Additional archival sources of data included minutes of meetings, CERN official and internal documents, administrative procedures, technical reports and specifications, contract and purchasing data, as well as funding application forms and tenders (both drafts and final versions), and company brochures, data sheets, academic publications, and other information on the technologies and businesses concerned. Furthermore, retrospective interviews of key managers in the case companies were conducted during 2004 to 2005. The interviews were semi-structured and aimed at checking facts and testing preliminary findings. Data analysis started in 2001 in parallel with the literature review and study of received theories, and has continued to date. The data have been examined and reviewed over a period of more than four years so far. This paper thus documents and reports the most recent results of the case analysis and of the overall study.

This methodology was motivated by concerns for both processes and theory building. First, the concern is with highly complex processes that take up to several years to unfold. Capturing the richness and complexity of these processes is virtually impossible without the case method and participation, which is also better suited to analyzing complex longitudinal phenomena such as inter-organizational communication and exchange, and the transfer of technology and knowledge. Second, the concern in this paper is with theory building. So far, no coherent framework has been developed for the influence on NBC of TT to research, and particularly from the venture team perspective. This paper aims at contributing toward such a theory by identifying mechanisms that contribute to the radical new business creation in big-science settings.

CERN, the LHC, and big science

The underlying public research organization in this study is CERN, the European Laboratory for Particle Physics. Its mission being basic research on particle physics, CERN is currently undertaking a major engineering and construction effort to complete a new particle accelerator complex, the Large Hadron Collider (LHC), by 2007. Once ready, this accelerator with 27 kilometers of circumference will be directing sub-atomic particles into collision trajectories at energy levels never used before, in order to experiment some of the latest theories in particle physics. The LHC project has been ongoing since 1994 and its implementation phase is well advanced. The project is a manifestation of the most diverse international collaboration between academia, public authorities and industry. The actual particle physics research at CERN is done by more than 500 member institutes and universities that also contribute to the LHC by constructing and financing very large-scale underground experimental laboratories and equipment. CERN also has its own organization of more than 2000 employees, whose activities cover fields ranging from engineering to administration. CERN being responsible for the accelerator machine and the civil engineering, a major part of its annual budget of around 1 billion Swiss francs (\$770M) is spent on the collider project. CERN has a substantial in-house engineering work force and R&D function and several specialized laboratories for testing and development. However, it should be noted that these facilities exist solely for the purposes of fundamental research on particle physics, and *not* for industrial innovation (see the Convention of CERN, 1953). CERN thus does not normally conduct commercial or sponsored research.

The LHC is a global effort, as all major economies on the globe participate in and contribute to the project, including the USA, Canada, Russia, Japan, China and India. In addition, some of the European Member States provide additional contributions to the LHC project. The budget for the project was fixed in 1994 for the entire construction period of more than 10 years with pre-set functional goals, although all the technologies to realize the project were not known at that time. The technologies involved cover practically all fields of engineering and in many cases are stretched well beyond the conventional limits. Some of the collider components are also needed in large quantities. Strict purchasing procedures oblige CERN to seek multiple supplier candidates and organize tendering competition in principle for all items (CERN, 1999). International competition is usually extremely tough, as CERN often contacts up to several tens of companies during the market-survey phase. Competitive tendering is also applied to subsequent purchasing, i.e. each purchase is one-off and in principle the cheapest bidder complying with the specifications wins the contract, whether or not it has previously supplied to CERN. CERN thus promotes so-called 'buying orientation', i.e. it seeks to obtain the lowest price, and uses multisourcing in its purchasing (Anderson and Narus, 1988).

CERN as a large intergovernmental and international research organization, and its experimental physics research and the LHC project, are often simply termed 'big science' (also 'big science center' and 'big science project'). Similar kind of large research centers, laboratories and projects, e.g. in astronomy, synchrotron radiation, and space research, are also called 'big science'.

The sample of NBC cases

The study focuses on five NBC cases with five companies in five different industries. They represent five different emerging technologies, covering production technology based on metallurgical processing, production technology for the manufacture of power electronic devices, superconductors, nanotechnology, and dosimetry. The sample includes both large corporations and small- and medium-size companies (SMEs), as well as a small start-up. The NBC teams in the cases examined are all relatively small organizational units, and the business they develop are considered new or radical either to the parent company or to the market, or to both. All the NBC cases and projects are called 'ventures' or 'venture projects' in this study, no matter whether they are corporate or independent venture companies, or just new business development projects. The

names of the companies and ventures, but not core features, are not reported for purposes of confidentiality.

In the beginning of the study, all except one of the ventures were new to CERN, which significantly helped studying and identifying the actual collaboration process from the very beginning, as well as the key factors and boundary conditions, and what kind of impact the collaboration had on the venture and its business development. All the cases had already had several years of R&D behind them, but had not yet reached the actual breakthrough on the general market. The status of their business-creation processes were the following at the time when cooperation with CERN started:

- Case 1: A new production technology was originally developed for military purposes several decades earlier. The corporation studied it in the 1980s and soon started the related R&D and business development. A corporate venture company was established in 1992 to continue the development. By 1998 the company had received a number of orders for small series, yet had no finished products. The corporation experienced a number of changes and a major merger. As the market for the venture was not the same as that of the corporation, pressures increased for the unit to focus exclusively on specific intra-corporate needs, and thus to act as an internal technology supplier instead of developing its own business on the global market place, although the latter was clearly the venture's own objective.
- Case 2: An SME had decided to apply its technical expertise in power electronics to a completely new market outside its core business. A tiny daughter company was recently established, with its own R&D and sales, and access to the parent company's advanced production technology enabling highly flexible and cost-efficient manufacture of both small and large production series. The venture was newly founded, fully technology-driven with no market research done, and enjoyed great enthusiasm. It received a few orders for one-off customization projects, and was sponsored by the owner of the company (a family) who had priorities other than quick return on investment. However, there was social pressure for the team and its leader to show their capabilities and prove the new business concept they had initiated.

- Case 3: A large state-owned corporation in the metal industry started to develop superconductors in the 1980s because of a specific customer need that radically departed from normal business. A venture company was established within one of the business divisions. One single contract with a foreign research institute provided the venture with the income and funding, as well as internal support, needed for normal operation and development throughout the 1980s. In the beginning of the 1990s, the company needed new customers and started cooperation with CERN, ultimately hoping to supply its technology to the LHC for which a proposal was being prepared.
- Case 4: A small university spin-off was established to commercialize a unique way of measuring temperature within extreme thermal ranges. Based on electronic transport in nanostructures, a technology concept for a calibration-free thermometer had been developed at the university laboratory. This meant that the underlying scientific principle was known at the time of the project, but the product itself was yet to be developed. The plans for future business were optimistic and one of the scientists was engaged to run the company and to continue R&D at university premises. In 1996, the venture was looking for potential customers, although the technology was still at a laboratory mock-up stage.
- Case 5: The company was the result of an MBO from an instrumentation company in the early 1990s. It brainstormed a radical new product and started to develop it, the management team being encouraged by very optimistic plans for a quick success. It was a great disappointment when the projected sales and planned progress were still not realized after five years of intense R&D that had taken a major part of the company's R&D resources. Changes in management and in project resources followed, yet the project was not killed off. There was a clear need for concrete business results and getting the product finished when contacts with CERN were established in 2000.

In the next section, the cases are analyzed using a cross-case analysis and received theories on innovation, technology management, and TT. Detailed case descriptions are not presented here for the purposes of avoiding excessive lengths of text, but short summaries are presented in the next section and in Table 1, and more detailed information is available on request from the author.

Findings

In this section, an analysis and the findings of the case study are presented. Then the resulting theoretical implications are elaborated against extant theories and received literature, followed by managerial implications for industry managers, research organizations, and policy-makers.

The two corporate venture cases of the sample indicate that a corporate venture developing a new technology-based business, which radically differs from corporate's mainstream business, found the cooperation with CERN instrumental in pushing the new technology and the emerging business model further on its trajectory toward market and a concrete business outcome. It also helped gain more established positions for the ventures within their parent corporations. One of the ventures was almost killed but could then accrue help from CERN in the form of neutral test results, joint development efforts, several supply contracts, and valuable references that helped it gain new customers as well as internal acceptance and recognition. Active exploitation of the reference value through relations with the media and corporate PR had an important role in gaining recognition.

In the case of a fresh new spin-off and daughter company of an SME trying to enter new markets requiring a business model that is radically new compared to that of the parent company, CERN boosted new business development in multiple ways. A company with well established and advanced, but very specialized and limited, technical expertise gained external know-how, extra funding, a long-term supply contract, and an important reference that it needed to extend to new markets and to achieve profitable business. For a university spin-off commercializing a new disruptive technology that had recently been discovered at a university laboratory, the sample order from CERN helped to boost product development by providing test results and facilities to the venture practically free of charge. The partner network of the international big-science center helped the company to benefit from highly specialized expertise and unique testing facilities. The small MBO-based company developing a disruptive technology radically changing the existing business models, also largely benefited from the cooperation with CERN by transferring its technology to CERN for testing and piloting. Furthermore, a major contract with CERN a few years later was the final breakthrough for the new business.

In general, the cases demonstrate the value of leveraging large-scale international big-science for business development purposes. The validation, testing and procurement by basic research of technologies developed by industry, including joint development and pilot prototype use by the research community, promote commercialization of these technologies and also satisfy multiple needs relating to new business creation. TT to CERN also generated significant knowledge inputs, which mainly took the form of very demanding test results. In some cases, CERN also provided first big long-term supply contracts and significant reference value. In all the cases, the benefits normally exceeded expectations. Table 1 provides a summary of the cases.

	Business creation needs	Internal support	Technology transfer	Overall outcome
Case 1	Production of complex shape thin wall parts, internal recognition, first meaningful references, 'bulging muscles' toward strategic partners much larger than the venture, generation of sales	Good level of autonomy, scarce resources but diminishing support for NBC, eight employees	Transfer of new tech samples to CERN, demanding test procedures on sample parts, transfer of prototype tech, extensive testing and piloting with prototypes, high-quality test reports, knowledge exchange between top experts on both sides	Extra funding from national resources, demanding test reports, data on piloting, order for pre-series prototypes, long-term breakthrough supply contract, automatization of production lines, full exploitation of the reference value, new status as a corporate core competence group
Case 2	References, launch of high tech image for the corporate, enhanced know-how, extra funding, supply orders	Moderate autonomy, moderate resources but lots of freedom, five employees	Transfer of new tech prototypes to CERN, technical discussions and know-how, critical and neutral testing and piloting, laboratory facilities and manpower, user feedback	Extra R&D funding, extensive test results, order for prototypes, order for the full series, full exploitation of the reference value by both the venture and the parent company, major breakthrough contract
Case 3	New customers and supply contracts, references, benchmarking with competitors, learning	Moderate autonomy, diminishing resources, tens of employees	Transfer of new technology samples and prototypes to CERN, knowledge exchange, demanding test results and reports, information on competitors	Extra funding from national resources, extensive test results, large long-term supply contracts, important references, internal recognition, new status as a strategic growth area, significant reference value for the whole corporation
Case 4	Need for customers for the radical new technology, further testing and piloting in environments not found in the laboratory, more R&D funding, references	Independent venture, very limited venture capital, two scientists as employees	Transfer of new tech samples to CERN, several valuable tests in unique testing environments, free use of laboratory facilities by people transferred to the research center	Extra funding from national resources, first order for the radical technology, improved expertise, important reference, potential customers and partners through the CERN network
Case 5	Need for customers for the disruptive technology, further testing and piloting, more R&D funding, references	No autonomy but not needed as the customers and processes with the mainstream business. Moderate resources, but starting to lack support and patience.	Transfer of new tech prototypes to CERN, demanding test procedures for the new technology, unique laboratory facilities including manpower, ideas for product improvements	Extra funding from national resources, unique first customer and a breakthrough supply contract, improved expertise, test results and piloting experience, user feedback, important reference

Table 1. Summary of the case evidence.

The positive impact of collaboration with an external partner is supported by research on social networks, TT, strategic management and open innovation (see e.g. Burt, 1992; Bozeman, 2000;

Chesbrough, 2003; Teece, 1986). Linking firms to non-business systems enhances the potential for innovation, and especially for radical innovation (Kaufman and Todtling, 2001). In addition, earlier research is in line with the findings that the motivation for companies to collaborate with a research laboratory is often the access to laboratory facilities or “user facilities”, as well as to other technical resources, expertise and knowledge found in the laboratories (Roessner, 1994; Papadakis, 1992; Bozeman, 2000). However, in the successful cases, CERN could provide the ventures even more than just laboratory facilities or technical resources. The outcome also included pilot use, user feedback, initial market, breakthrough supply contracts, and reference value. Although this is rarely dealt with in literature on research laboratory-industry collaboration, some of these outcomes are nevertheless discussed in the innovation literature. Bower and Christensen (1995) and Souder (1989) emphasize the importance of locating and tapping first a small peripheral market for technology push before moving on to more glamorous end uses or to the company’s usual mainstream market. The research center could be considered as such a ‘small peripheral market’. Furthermore, it could be defined as a ‘lead user’. Lead users are those who “face needs that will be general in a market place, but they face them months or years before the bulk of that market place encounters them” and who are “positioned to benefit significantly by obtaining a solution to those needs” (von Hippel, 1988: 107). In our cases, CERN fits this definition of lead users, although the research center was not the *source* of innovation but rather had a role toward the *end* of the innovation process. Tuomi (2002) goes beyond the conventional concept of coupling innovation to the market, and argues that innovations become innovations when they are taken into *meaningful use in social practice*, referring to the cases of the World Wide Web and the Linux operating system as examples. While CERN fits the above definitions of ‘small peripheral market’ and ‘lead user’, Tuomi provides a good explanation for what the evidence actually tells us. The research center provided the case technologies with a social practice and use that also was meaningful, first, in terms of its high reference value, and second, in terms of its large global network of major universities and scientists. On the other hand, the ‘meaningful use’ of the new technology in the big science setting was not just about big science acting as a market or a customer as in a classical B2B relationship. CERN’s know-how, expertise, pilot users and laboratory facilities on the site and within its large partner network, together with its reference value, were unique compared to usual B2B customers. It should be emphasized, however, that this significant role of the research

center did not require any additional efforts from the center compared to its normal operations and activities. The cases were *not* about commercial or sponsored research but about companies working with the research center in order for the latter to validate new technologies it was not familiar with but which provided a potential fit for its needs.

Based on the evidence, it can thus be summarized that the venture projects were in need of *external complementary resources* (Teece, 1986) such as a research partner, testing facilities, laboratory equipment, neutral test results, pilot users, user feedback, and specialized technical expertise, and the research center was able to provide the case ventures with all of the necessary complementary resources. These external resources also included external R&D and project funding, and external broker service, which, while not directly provided by the research organization, were indirectly attracted by the fact that the venture collaborated with the center. Furthermore, the center provided some of the ventures with a *small and peripheral but meaningful market and usage*, and even the first breakthrough contracts as well as references that became valuable not only on the global market place, but also in relations with strategic partners, as well as internally within the case companies. A generic process model can be identified that is common to all the cases, covering the phases of technology sampling, testing within the research partner network, preparation and delivery of test reports, industrial prototype development and transfer to research, piloting with prototypes and user feedback, and in some cases also the supply of finished products.

These findings seem to be independent of the type of company or industrial sector. However, in large companies the radical development projects often experienced resistance, lack of resources and even rejection. These findings on resistance are supported by previous research (Ansoff and Brandenburg, 1971; Hannan and Freeman, 1977; Burgelman, 1983), and is explained by structural inertia and inflexibility, the company value network, structured new product development (NPD) processes, and patterns of resource allocation that do not favor radical initiatives aiming at markets other than the company's mainstream market (Bower, 1970; Pfeffer and Salancik, 1978; Burgelman, 1983; Ettlie et al., 1984; Hannan and Freeman, 1984; Christensen and Rosenbloom, 1995; Tushman and O'Reilly, 1997). Consequently, scholars and consultants typically propose major changes in management practices, business processes, and even in corporate culture and strategies. However, the case projects in this study advanced even

without these changes. It seems that radical NBC may survive and succeed even without major strategic changes. Most of the cases had only scarce resources, and there was a continuous threat that resources would be further cut (see the sample descriptions). Interest in working with a research center might actually increase when companies' own internal R&D support is not sufficient (Roessner, 1993; Katila and Shane, 2005). A moderate level of internal resources drives companies to seek external resources from public research that, as evidence shows, may significantly help the venture with business development. Furthermore, as indicated above, the research center can also provide significant added value without the center being obliged to take any additional actions or to change its own processes and procedures compared to its normal operations.

Naturally, the case research center was not the only external resource and partner along the long trajectory from technological discovery to new business. Even during the collaboration project there were other important stakeholders such as the company hosting the venture, external project funding agencies, third party brokerage service, the government, and the general market. In addition, ventures had research partnerships with universities and laboratories ongoing at the same time with research center collaboration. However, the collaboration with the research center, due to the unique combination of all the above-mentioned factors accrued from the joint collaboration, somehow triggered all the cumulated previous efforts and investments in the venture and transformed them into a business breakthrough. It is possible that without the big science collaboration, the companies might still struggle in a similar situation as had prevailed for years during periods prior to the research center collaboration.

Implications for theory

It is proposed here that an international research center for fundamental research may have a significant role to play also and especially toward the end of the commercialization and new business creation process by transferring (or 'actively receiving') technologies from industry to its research. This finding has several implications for theories on technology transfer and innovation:

First, it proposes *TT from industry to research*. Research on TT tends to concentrate on the TT from universities and laboratories to industry (Harmon et al., 1997; Bozeman, 2000). Transfer of technology from the public research sector to the economy has been studied and documented extensively, including spin-off firm formation, patenting, licensing, and R&D collaboration agreements (Beise and Stahl, 1999; Bozeman, 2000; Di Gregorio and Shane, 2003; Feller et al., 2002; Mansfield, 1991; Pavitt, 1991; Shane, 2002). In addition, there are also studies on TT to governmental users (Bozeman et al., 1978; Lambright, 1979), on the dual-use of technology (Watkins, 1990), and on the public sector being the first user (Dalpe et al., 1992). However, literature rarely discusses TT from industry to research. This paper introduces a model of *reverse TT*, i.e. transfer of new industrial technologies to public research, which helps industry commercialize new technology, and catalyzes the associated new business creation.

Second, it is about *TT with basic research*. The basic research chosen for this study was the fundamental particle physics research at CERN and within its global network of more than 500 institutes and universities. CERN and the related physics research do not conduct any contract or sponsored research that would be based on industrial needs. Cooperative R&D agreements exist, but unlike many industrial collaborations with research, their aim at CERN is to exploit industrial capabilities to help CERN to accomplish its own research objectives, not to serve industry in industrial R&D. While TT with basic research is not new, and studies on basic research-industry cooperation exist (Hameri, 1996; Hameri and Vuola, 1996; Rogers and Bozeman, 1997), the *TT to basic research to catalyze business development* is believed to be a new concept. Furthermore, even though it is with basic research instead of applied research, this new concept generates concrete business results in the economy relatively quickly.

Third, it has implications for the *conception of innovation process*. Several studies emphasize the *interactive* modes of the innovation process, criticizing the original linear innovation process model as too simplistic (Lundvall, 1988; Cohen and Levinthal 1990; Roessner, 1993; Inkpen 1996; Amesse and Cohendet, 2001). The cases strongly support these contributions, as the cooperation between research and industry was interactive in nature, and knowledge was transferred in both directions. However, the actual technology or the technological artifacts were transferred only one way, i.e. from industry to research, as discussed above. These artifacts included new technology samples, prototypes, and in some cases also finished products that had

resulted from the cooperation. The findings presented in this paper thus extend our understanding of the interactive modes by stating that TT with research may also be reverse, and second, that it may have a significant role *toward the end*, rather than the front-end, of industrial commercialization and NBC process. Furthermore, the process from technology to business is long and complex. Previous research has argued that, in the case of new technology and discontinuous innovation, several technology trajectories and many years of development and research typically precede the product-oriented development (Dosi, 1982). The present research shows that new technology may actually originate from a scientific discovery followed by many years of research, then be transferred to industry and change the owner and the host several times over years, and have several interactions (and TT) with several research partners along the process. The process may take up to 50 years or more, and actually the very first single action of TT from research to industry has only a minor role in the total picture. Neither is the market entry a single point in time but may actually take years, as the product and the market develop in parallel, somewhat symbiotically (Utterback, 1971; White, 1978; Souder, 1989). And finally, as discussed above, it may actually be the reverse TT *to research*, and not the original TT *from* research, that commercializes the technology and triggers the takeoff of the new business. A case example is illustrated in Figure 1.

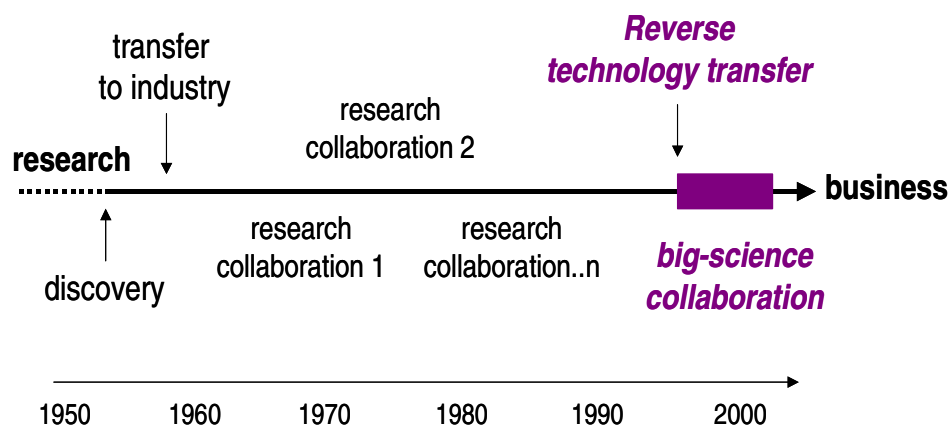


Figure 1. A case example of the overall trajectory from discovery to new business.

Fourth, this study increases our understanding of big science TT and *big science-industry dyads*. The conventional big-science TT is a process where big-science technologies are transferred to

users and industrial companies. As an example of this form of TT, several studies have reported on CERN's role in the birth of the World Wide Web (Hameri and Nordberg, 1998; Berners-Lee and Fischetti, 1999; Tuomi, 2002), while another study have documented how university research at CERN may result in spin-off companies (Byckling et al., 2000). Most of the innovation studies on big science, however, have focused on the conventional business-to-business (B2B) dyad, where big science orders products and services from its subcontractors, and on the secondary benefits to Member State industries accrued from big science procurement (Schmied, 1977, 1982; Streit-Bianchi et al., 1984; Autio et al., 2003). There is much less research on a systematic use of the 'hidden' resources of CERN for the benefit of new industrial technologies. A recent study (Vuola, 2004; Vuola and Hameri, 2005) has investigated this option, but mainly from the research center and policy-maker perspective. Guidelines to companies, and especially to those that are new to big science are clearly lacking. The benefits are typically accrued by established industrial partners only (Harmon et al., 1997; Autio et al., 2003). One of the major implications of the findings of this study is thus that *new technology ventures* can develop their business in many important ways and also lead them *to a business breakthrough by entering and transferring new technology to big science*.

Fifth, the study has implications for our understanding of the *type of company* collaborating with research. According to Harmon et al. (1997), technology transfers are typically to large companies, and, quite surprisingly, serve to extend and improve existing product lines and not to promote radical initiatives. Rogers and Bozeman (1997), on the other hand, suggest that smaller companies succeed better than large ones. The evidence reported in the present paper shows that small ventures developing radical new business indeed could accrue benefits from the collaboration with research. Furthermore, it suggests that *radical venture projects within large companies are in a somewhat similar position to those in small companies*. Ventures in both large and small companies seem to succeed, assuming that the collaboration project and the commercialization process in general, are well managed. Furthermore, in addition to Autio et al. (2003) who recommend focusing on technology-intensive procurements, this study proposes that the seemingly less technology-intensive procurements and companies could also be concerned, as the company, although its products or the company itself are not necessarily considered high tech, may have *NBC* projects and *production* technologies that are new or even radical for the company. And finally, earlier research (see e.g. Ettl et al., 1984; Souder, 1989; and Rogers and

Bozeman, 1997; Tushman and O'Reilly, 1997) often emphasizes the role of top managers in order for new technology project to lead to marketed products. While also in this study top management support was found important, it was important mainly only when commercial cooperation with the research lab started, i.e. up to several years after the actual TT phase was initiated between experts and engineers on both sides. The advantage of this new mode of TT is eventually the fact that it *provides radical venture projects with good prospects of business success even with just moderate support from their parent organization and top management.*

Managerial implications

The study also resulted in important managerial implications for industry managers, research organizations, and policy-makers, which are presented below.

Implications for industry managers

For venture teams, R&D and business development managers, and new technology 'champions': Ventures should be much more active in seeking collaboration with public research centers. When it is well managed, collaboration with a research center may provide the venture and NBC with the major elements needed for the new technology to become innovation and the venture to transfer into an established business: testing facilities, laboratory equipment, test procedures and results, pilot users, user feedback, and specialized technical expertise. In addition, the collaboration may indirectly attract additional project funding, which, while not directly provided by the research organization, is attracted by the fact that the venture collaborates with a research center. Third, research, in case of big science, may also provide an initial market and meaningful use for the technology and the first breakthrough contracts as well as references that are valuable in the general market place, in relations with strategic partners, and also internally within the parent company or corporation.

For corporate management: Radical projects differ from incremental development. Corporate management should allocate resources also to radical initiatives that do not necessarily serve the existing customers of the mainstream business. They should also allocate these new technology-based business development and venture projects with sufficient independence from the business

models and practices of the surrounding mainstream microenvironment, and provide the venture with continuous basic funding. The funding does not need to be excessive, quite the contrary, as this may drive the venture to seek external complementary resources and collaboration with public research. This kind of collaboration typically accrues multiple benefits to the venture, and may also lead to its breakthrough into profitable business. External complementary resources and technology transfer with research is thus recommended, and quite surprisingly, especially *resources from and collaboration with centers for basic research and toward the end of the innovation process and NBC*.

Implications for research organizations

Basic research may have a significant role toward the end of new technology-based innovation and NBC processes. While this contribution to successful innovation and business creation in the economy certainly also have *indirect* positive impact to the research organization, it also has a *direct* effect in saving costs. New radical innovations tend to solve technological problems in the most cost-effective way. However, these new technological developments are not always available for the research organization, as companies are not necessarily interested in business with public research: the market is perceived to be too small, specific and narrow without economies-of-scale, and relatively difficult for a newcomer to enter. Also the purchasing policies of research organizations may not encourage, as contracts are by default adjudicated to the lowest bidders. Research centers should thus be open to new partners and technologies, and encourage and help them start partnerships with the center. In order to maximize the cost savings, they should focus on ventures with a target market outside the public research, i.e. so that the new technology is not primarily transferred to the research center in order to be commercialized there alone, but just to help with the venture's trajectory to final end markets. There is no need to change financial rules, purchasing procedures, or the mission of the organization. The only requirement for the research organization is to be flexible enough to replace the usual B2B approach and some of the established industrial suppliers with *reverse TT from new technology ventures* having sufficient basic autonomy and support within their own organizations. The reverse TT means that new technology is transferred from industry to research for the mutual benefit of both of the parties. This new mode of TT also generates concrete business results from basic research relatively quickly compared to traditional TT from

basic research to industry. Research organizations could also consider new metrics for industrial return in order to encourage collaboration between its own staff and industry venture teams.

Implications for policy-makers

Basic research is justified and evaluated by its research results. Despite significant results and increasing understanding of basic scientific phenomena, the justification for large research centers and big-science projects is often questioned in the public. Funding agencies and governments push formalized TT activities and procedures for research centers with the aim of turning basic research results into industrial products and innovations. Policy-makers, as well as scientists, often tend to think, “if only industry and public research could get together, commercial innovations would arise”. In its report on science and technology indicators the European Commission states that “An important support mechanism for the realization of the knowledge-based economy is strong industry-university co-operation. This allows for the rapid conversion of scientific knowledge into commercial innovations with strong social and economic benefits” (EC, 2003: snapshot 6). This statement implies that innovation emerges automatically when industry and research are put together, and thus mistakes invention for innovation. Scientists and researchers as well as R&D engineers also tend to underestimate the workload needed for the commercialization and productization as well as for relationship building with users and customers. This study shows that it is a long journey from research to concrete business outcome. The trajectory typically includes a number of, and also several types of, collaborations between research and industry. The study introduces a new innovative way of using reverse TT between a new technology venture and a large research center toward the end rather than front-end of the innovation process to commercialize new technologies and create new businesses and jobs in the society. Research centers can provide a venture with the multiple resources a new venture requires for concrete business outcome. The reverse TT is only one but seemingly an important mode of collaboration and TT along the trajectory to the established business. This significant role of the research center does not require any additional efforts from the center compared to its normal operations and activities focused on fundamental research. It is not about contract or sponsored research but about companies working with the research center in order for the latter to validate new technologies it was not familiar with but which provided a potential fit to its needs. Nor would additional TT efforts be required on the part of the research

center. Without extra efforts from the research organization, this new mode of TT generates concrete business results from research, and from basic research in particular, and does it relatively quickly compared to traditional attempts to transfer technology from basic research to industry. In Europe alone, out of the total of €175b devoted on R&D by EU-15 (EC, 2003), it is estimated that about 1b€ is used by intergovernmental research projects to purchase technology from external parties (Vuola and Hameri, 2005). This may not be much, but if this investment were used to help new ventures, the indirect benefits would become manifold for the society. This might even provide the necessary new “justification”, while previous research shows that while there are significant knowledge benefits from the traditional TT, there has been little direct evidence that research laboratory-industry partnerships in the past have been wellsprings of jobs or new businesses, and that tangible benefits would have been quickly realized (Bozeman, 2000).

Another implication for policy-makers is that new technology ventures developing new businesses that radically depart from the mainstream business, face difficulties not only in start-ups but also in SMEs and large corporations alike. Commercialization of new technologies and the development of radically new businesses is challenging even for leading firms with skilled management and great resources. Public R&D funding and innovation support should not make a separation between small and large companies but should focus on *radical* projects in all kinds of companies. Incremental customer-driven product development usually does not need public support, as funding for such development should normally be found internally within the company. Radical projects, however, require external resources, irrespective of the size of the company.

Conclusions

This paper introduces a new concept of reverse technology transfer, i.e. TT from industry to basic research. The new concept is most useful when it is an integral part of the overall industrial NBC and toward the end of the process from technology to the market and to established business. Basic research may thus play a significant role also toward the end of the innovation process. The paper suggests that through collaboration with a big science center, a new technology venture that radically differs from the mainstream business models, and has only

limited internal support and resources will grow up into a new business with the help of a set of complementary resources directly and indirectly accrued from the joint project with the research center, in particular when combined with a meaningful use within the practice of its large and complex social network.

Reverse TT is best applied to new technology venture projects, which develop new technology and radically new business before having reached their breakthrough on the general market place. The target market of the venture should be outside public research and in any case not in the research center; otherwise there is the risk of being too expensive in competitive tendering. Consistently with Kim and Mauborgne (1999), companies should also be careful with pricing, as technology ventures tend first to test the water by targeting novelty-seeking, price-insensitive customers at the launch of a new business idea, and then over time drop prices to attract mainstream buyers. This is not possible with public research with strict purchasing procedures that award the lowest bidder of all competitors. The technological field should naturally be among the technologies needed by the research community. Collaboration should start by preference with informal expert-to-expert interaction, sample transfer, and testing and piloting, and not directly with the usual B2B sales approach. Reference value should be fully exploited by organizing press conferences and keeping in contact with the media.

The study was limited to CERN and fundamental physics research, but many other research organizations in general operate in a similar way. Future research could include other big science centers and projects, as well as governmental, federal and intergovernmental research laboratories, and other research organizations. The paper also suggests more focus on the actual business-creation process, as research on innovation and TT (as well as inventors themselves) tend to focus on the front-end of innovation and seem to underestimate the efforts needed toward the end of the innovation process. Building and managing user relationship was also found to be of great importance. It is thus suggested here that future research on technology transfer would incorporate research findings also from other disciplines such as marketing in order to increase our understanding of the actual processes taking place when new technologies are taken into various social practices.

Furthermore, a more holistic picture of technology transfer processes is needed. In most of the cases in this study the technology was originally developed at universities or for the military, and then transferred to companies. However, the very first transfer *from research* to industry is only part of the total picture within the overall NBC process. In the studied cases, several years or even decades later there was still no actual breakthrough on the market and the final business outcome was still lacking. In order for research on TT to have more practical and economic relevance, future research should cover the whole transfer process from technology up to the market breakthrough and up to concrete business outcome.

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