Before the Start-up

The case of academia-industry collaboration

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Abstract

The nowadays prevalent view of the university, i.e. science, as a direct source of innovation and economic growth (e.g. Etzkowitz & Webster 1995, Rider 2009) has during the last two decades greatly affected the engagement of Swedish universities in the issue of commercialisation. Accounting for different types of strategies of achieving efficient commercialisation processes, the university commercialisation initiatives bring to fore questions about the requirements of successful commercialisation, as well as the particular conditions of creating businesses on the basis of scientific discoveries (e.g. Baraldi et al. 2014).

By engaging in activities intended to commercialise research and thus induce innovation, universities are undergoing both a political and an organisational transformation. Politically, the basic goal of knowledge production for the sake of knowledge itself is expanding (or changing) to include the goal of subsequent development and marketing. Thus, what before was seen as tasks of other types of activities and actors is now included in the political agenda of *science*, and of *the university*. Organisationally, these goals affect how research is organised in terms of research directions and objectives but also the university organisation in terms of including special units for legal counselling, patenting, spin-off activities etc. Another part of this transformation is the forming of a number of commercialisation projects which need to relate to both an academic research environment and a commercial or business type of situation. This paper investigates what this means in terms of managing a science-based commercialisation process.

An interactive perspective of innovation proposes that in order to get a widespread use, any attempted innovation needs to relate to three different empirical settings; *development*, *production* and *use* (Håkanssson & Waluszewski 2007). By investigating a particular type of university organized commercialisation venture, involving both the university and several industrial partners, the overall research question of this paper is how the requirements of these three settings affect science-based commercialisation processes and ventures.

Introduction

Today the university is not just treated as a research and educational institution but also as a direct source of creating commercialization ventures and innovation (e.g. Meyer, 2003; Rider, 2009). Perceived as a direct way to impact economic development and growth, policy makers are directing substantial resources in the support of academic entrepreneurship and technology transfer (Seigel et al., 2003)[2]. Not least in relation to licensing and start-ups (Bower, 2003). However, the support does

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not just come in the shape of financial resources or legal and patenting consultancy for the individual wanting to commercialise their research, based on governmental initiatives universities also take on a proactive role in the commercialisation of research (Ibid). Through the forming of innovation facilitating organisations (holding companies, TTOs, incubators etc.), universities participate actively in selecting, further developing, commercialising and exiting science-based commercialisation ventures (e.g. Baraldi &Waluszewski, 2011).

Accounting for different types of strategies of achieving efficient commercialisation processes, the university commercialisation initiatives bring to fore questions about the requirements of successful commercialisation, as well as the particular conditions of creating businesses on the basis of scientific discoveries (e.g. Baraldi, Ingemansson, Launberg, 2014). The relationship between academia and industry has long been an object of study (e.g. Mansfield 1995; von Hippel, 1988), and these university initiatives of late has also spawned a wide range of studies and literature investigating the impact of such policies and commercialisation initiatives on both science and business. In an extensive literature review of such studies Rothaermel et al. (2007) refer to the field as that of *University entrepreneurship* which includes investigations of the *qualities of the universities* producing research which becomes commercialized, of the universities own *innovation facilitating systems*, of the *start-ups* that are created, and finally the surrounding *context* of innovation promoting policies as well as the "receiving" industry related to the particular research. A substantial part of this literature mainly focuses on identifying factors impacting the success rate of science-based commercialisation efforts. Such investigated factors for instance relate to access to financial resources (e.g.), the availability of business knowledge (e.g. Lockett et al., 2005), and the particular features of the university and their potential impact on the commercialisation ventures (e.g. Gregorio & Shane, 2003). Generally, these studies denote commercialisation as a process through which something purely *scientific* (i.e. a research result) takes on a "commercial form" such as a patent, license or a start-up. In trying to identify success factors (and thus also challenges in succeeding with commercialisation of academic and public research) these studies often depart from the assumption that the main determinant of whether universities or other public institutions can be seen as successful in commercialising research is the *quantity* of licences or start-ups/spin-offs that are created, while some also include firm growth (i.e. number of employees).

This paper will however argue that these are just initial steps of turning scientific research into innovation (i.e. the widespread use of any new solution), which can be seen as the ultimate goal of technology transfer. If innovation is the goal, successful or efficient commercialisation must also include *production* and *use* of a new solution, be it scientific or other (e.g. Håkansson & Waluszewski, eds. 2007; Ingemansson, 2010). Therefore, in order to understand how the work of universities to commercialize academic research relates to innovation, the relation between individual science-based solutions (e.g. licenses and start-ups) and relevant producing and using settings must also be included in the analysis. This paper thus departs from the standpoint that in order to theorize the success and failure of commercialisation of science-based solutions and start-up ventures, an understanding of how they fit into existing industrial structures must be pursued.

To discuss how university-organized commercialisation efforts need to relate to *developing*, *producing* and *using settings* (Håkansson and Waluszewski, eds. 2007) in the pursuit of innovation, as well as how these settings need to relate to each other, a case study of a joint commercialisation project of academia and industry is presented. This example is especially interesting as it contains the elementary components of a nowadays "classic" commercialisation and innovation facilitating model; *academic research* and a scientific breakthrough, *industry* and active industrial participants, and *university innovation facilitation* driving and managing the academia-industry collaboration. As such it allows for the study of how one new science-based solution need to relate to several different actors and resources; settings of both *science* and *business*, and settings of *development*, *production* and *use*.

Before learning more about the specific case, we will have a look at how some of the 'problems' of successful commercialisation of science-based solutions is set up in the university entrepreneurship and start-up literature, as well as how such a challenge is understood from an industrial network approach.

Theoretical considerations

Challenges of university entrepreneurship and science-based ventures

The content of this literature review departs from the question: what are the often identified challenges and failures of NTBFs (new technology-based firms) and university spin-offs? The reviewed articles have thus in some regard all investigated how NTBFs and university spin-offs should be promoted and which are the necessary resources. One central challenge adheres to the access of appropriate knowledge. Lockett et al. (2005) identifies the "knowledge gaps", which new ventures in the interface between public and private faces at different stages of the commercialisation and spin-off process, as one of the most important areas to which further attention must be brought. Identified as the most essential resource of gaining a *competitive advantage*, the authors see knowledge and organizational learning as crucial to learn more about in terms of the business skill sets and capabilities that might be missing at different stages of the new venture. As also identified in other studies, such knowledge can be missing and thus required at several levels; at the level of the individual academic (Lockett et al., 2005; Meyer, 2003), at the level of the start-up team and management (e.g. Rothaermel and Thursby, 2005), and at the level of the innovation facilitating units, i.e. TTOs, incubators, innovation offices etc. (e.g. Seigel et al., 2003; Moray and Clarysse, 2005). Regarding the individual academic it is brought forth that usually academic researchers do not possess the required business knowledge for starting and running a spin-off company and therefore should leave business-specific tasks to other more skilled business people. However, at the same time it appears important that the inventor is devoted to the new venture, but in regard to more technical issues of the invention, and that the significance of this commitment increases with time (Lockett et al., 2005). At the level of the start-up team it is suggested that university spin-offs also often consist of teams with insufficient business capabilities, and thus that the composition of the management team needs further attention (Rothaermel and Thursby, 2005). At the level of the innovation facilitating units it is proposed that as the transfer of knowledge between the incubator (or other innovation facilitating units) and the new venture is so important, the knowledge and skill set of the incubator also becomes a crucial resource for successful commercialisation. Bower (2003) also points to the importance of business and commercial knowledge as she shows that most European NTBFs are spin-offs from established companies and are run by senior personnel with previous employment in those companies. She proposes that academic spin-offs usually lack such competence and therefore face particular challenges and difficulties. Further she identifies understanding about the customers as well as appropriate usages of the new technology as two crucial aspects of business knowledge required to succeed with a new venture. As summarized by Lockett et al. (2005, p. 991) these studies point to "*the importance of the acquisition, development and integration of knowledge in the development of spin-offs at PRIs*[3]*"*. In regard to NTBFS in general (not just academic ventures) it is also through a number of studies concluded that industry-specific work experience is of particular importance in terms of firm growth (e.g. Feeser and

[3] PRI stands for public research institutions

Willard, 1990; Colombo and Grilli, 2010). This suggests that it is not only business knowledge in general that is needed, but knowledge about the specific industry in terms of central actors and resources.

Besides business knowledge among the management team (i.e. human capital), financial resources, and not least venture capital, is an often crucial resource associated with NTBFs and start-ups:

> *The entrepreneurship literature generally agrees that human capital of founders and access to venture capital (VC) are two key drivers of the success of new technology-based firms (NTBFs).* (Colombo and Grilli, 2010, p. 610)

The basis for such a claim is studies which show that the access to venture capital has a positive correlation to firm growth (measured as number of employees). However, there are less studies focusing on *why*. The studies that do, however, conclude that it is connected to the knowledge and business practices of the venture capitalist rather than the function of the money in itself. This means that the type of financial resource that is typically associated with the success of start-ups also has to do with knowledge. According to Hellman and Puri (2002) venture capitalists provide *professionalization* of start-ups by assigning CEOs and filling other central positions in the company. Colombo and Grilli (2010) distinguish between companies with different levels of industry-specific knowledge and state that venture capital is more valuable to start-ups with a lack of such knowledge. Gompers and Lerner (2001) also state that venture capital is an investment form that only suits particular type of companies, and thus conclude that VC is not a suitable type of investment model for all start-ups or ventures. In addition they conclude that different types of investment capital and funding is suitable at different phases of a venture; while VC can be suitable for a particular type of company at a particular moment in time, the same company might need a different type of funding at a later stage (ibid.). In the case of science-based and academic start-ups Lerner (2005) expresses scepticism towards venture capital as there is a low possibility of the ventures creating the expected returns, both for the investors and for the institutions where the inventions stem from. The main explanation offered is that often these types of ventures are in a very early stage in terms of new technology, which means that it is a very risky and long-term commitment for this type of capital.

The connection between financial resources, and particularly venture capital, and the effects it creates for start-ups is thus an investigated one. However, these investigations mainly concern the internal organisation of the individual start-up or the possibilities of exiting the start-up in terms of a public offering, acquirement etc. Less attention is paid to the innovation journey of the solutions and technologies on which these new companies and ventures are based.

An industrial network approach to start-ups - the challenge of development, production and use

From an industrial network perspective any new solution developed through science or other activity that is to become an innovation needs to fit into a socio-material world consisting of earlier investments and ongoing activities. Creating a commercial value of new technology is therefore about embedding processes through which technical and organisational resources are combined in new ways. An essential part of innovation processes is how well these resources match; the more anything new fits with existing investments, the less additional investments is needed to implement it. The potential- as well as realised value of any new solution or technology thus lies in how it can be combined with the structure of existing solutions to which it has to relate - technical and organisational systems which are necessary for the use of the new solution. However, it is not just one system the new solutions need to fit into, but rather three different but interrelated systems; a *developing*, *producing* and *using* (Håkansson and Waluszewski, eds., 2007*)*. These are three empirical settings represented by actors and resources which engage in the innovation process in distinctly different ways in order to create value; while development is concerned with exploring different options, remaining flexible and being open to the possibility of re-evaluating development directions (e.g. Rosenberg, 1994; Van de Ven et al., 1999; Håkansson et al., 2009), large-scale production necessitates "locking" (i.e. standardising) both physical and organisational solutions in relation to one or a few particular production processes (Dosi, 1982; Håkansson and Waluszewski, eds., 2007). Furthermore, in a using setting the new solution or technology needs to be able to create value for several customers by interacting with a range of different solutions (e.g. Rosenberg, 1982; von Hippel, 1988). There are thus several and different socio-material environments with which a new technology needs to interact and fit in order to become an innovation. In addition, the way the new solution fits into each of these three respective settings, affect the other settings. From this perspective, one major challenge identified for NTBFs is therefore how to create value for such distinct but still interrelating settings.

In relation to university spin-offs, this challenge is identified as possibly even greater (e.g. Waluszewski and Ingemansson, 2009; Ingemansson, 2010). In this case new solutions that have been developed in an academic environment through scientific research are to be "transferred" into a business environment and "transformed" into commercially valuable products and services. The transformation thus refers to turning scientific value into commercial value. This is often interpreted as the process of securing a patent, a license and/or forming a start-up in relation to the research results that are to be commercialised, however these are rather formalised measures made only in relation to the solution itself and not to the contexts in which it needs to fit in order to become an innovation. For instance, while patenting is one way of protecting 'unique' solutions from potential competitors it is not necessarily in any way related to embedding these solutions into potentially value-creating settings. Similarly, a start-up needs to become related to the industrial environments in which it is meant to contribute to. From an industrial network perspective this means that the new technology, start-up etc. needs to become embedded in established producing and using contexts through the forming of business relationships and adaptation processes of both technical and organizational resources. In the established producing and using settings, these are resources which through the use of particular technologies as well as adaptations to particular suppliers and customers have gained specific features, and are interrelated to a larger network of resources. For new science-based solutions and start-ups to become commercially successful and thus represent innovation, they need to fit into the *specific* and *diverse* resource networks of suitable producing and using settings.

Before the challenges of the studied commercialisation process of this paper are presented, the method of the study and this paper will be addressed.

Method -performing the case study

To perform the investigation of the presented academia-industry collaboration a case study involving interviews and participating observations of multiple actors over time has been made. Interviews were made every year between 2010 and 2014 and involved the central actors of the project; the academic researchers, the commercial partners and the innovation facilitating unit. The participating observations were made during two project meetings involving several or all of the project members in 2010 and in 2012. Written sources have also been used, such as project descriptions and scientific publications. In addition, in 2011 three bachelor theses were performed investigating the industrial networks of the commercial partners involved in the project in terms of suppliers and customers. The overarching purpose of the theses was to investigate the commercial potential of the new technology in terms of how these partners could engage in the commercialisation project due to their respective business networks.

The case study has investigated the *interfaces* between the settings of development, production and use in terms of the actors involved in the respective settings and their central resources (technical resources; products, facilities, and organisational resources; knowledge, and relationships). By making the new technology the focus of study, and how it interacts with these interfaces, the purpose has been to gain insight into the ways in which science-based technology needs to fit into established business networks, and what role innovation "intermediaries" or facilitating actors can play in that process.

The case study

The initial scientific research and development -the idea of a new battery takes shape

During the 1990s a research group at the *Department of Nanotechnology and Functional Materials* at the *Ångström Laboratory* at *Uppsala University* started to do research on the cellulose of a particular type of algae - *Cladophora*. The research work, which was led by an associate researcher specialised in nanotechnology and a PhD student with a degree in pharmacy, was based on developing knowledge about this particular material for the purpose of finding qualities suitable for biotechnical applications. The research was focused on learning about the nanostructure of the material, i.e. the particular features of its surface area, and how this could be used for biomedical and pharmaceutical purposes. It was concluded that this cellulose had a very high surface area (~100 square meters per gram), a high crystallinity[4] and could be dissolved in water, and that as a result had superior qualities compared to the cellulose traditionally used in pharmaceuticals (tablets). This created an interest at the *FMC Corporation*, a global supplier of chemicals for agriculture, food industry and pharmaceuticals and a world leading producer of algae cellulose, which first heard about these results in 1999 during a meeting at a different department at Uppsala University. The qualities of the cellulose appeared very interesting from FMC's point of view in terms of potential industrial applications. FMC was also the only supplier in the world of this particular type of algae cellulose and was therefore a very interesting collaborator from the research group's point of view. This resulted in what would become a withstanding collaboration between one of FMC's divisions, *FMC Biopolymer* (now *FMC Health and Nutrition*), and the research group at the Department of Nanotechnology and Functional Materials at Ångström.

During the first years of the collaboration the work mainly concerned potential applications for pharmaceuticals. The first idea was based on using it for surface coating of tablets to protect moister sensitive pharmaceuticals against degradation, but after initial development it turned out to be too difficult to manufacture and hence embed in the existing production processes of FMC. A few years later, in 2004, new features of the cellulose were discovered by the research group which meant that it could be used as a stabilizer in pharmaceuticals. When contacted again FMC found this application useful and also patented it which made them the sole company that could produce and use the cellulose for this purpose. The research at Ångström continued and the idea that the material could be used for conductive purposes was starting to form. The question they asked themselves was: what would happen if we could make a material with this high surface area to conduct electricity? Cellulose is however not a conductive material, rather it is used as an isolator of electricity. However, due to the

[4] This means that the material is organized in a particular structure (compared to an *amorf* material which is organised in a random structure).

high surface area of the algae it had great potential of interacting with the surrounding environment and with other materials, and therefore also had the potential of interacting with and containing a great deal of ions. For this purpose the cellulose was coated with a conductive type of plastic (polypyrrole) which made it 'electroactive'. By placing this joint material in a fluid and bringing on a voltage, ions could be "forced" into the material from the surrounding fluid. The idea was that this material could be used for biotechnical and biomedical purposes as a way to filter both desirable and unwanted protein from different types of solutions. However, in this process it was discovered that the material could hold a lot more ions than expected, and as the basic idea of a battery is that it should contain as much ions as possible to get a high energy density, the idea that it could be used as a battery was born. In a publication of these results in the scientific journal *Nano Letters* (Nyström et al., 2009), in which the material was shown to efficiently charge and discharge (thus functioning as a superconductor), it was stated that: "…*we introduce a novel nanostructured high-surface area electrode material for energy storage applications composed of cellulose fibers of algal origin individually coated with a 50 nm thin layer of polypyrrole. Our results show the hitherto highest reported charge capacities and charging rates for an all polymer paper-based battery*."(Ibid.). This became one of the most read articles of the journal the same year it was published, 2009. It was these initial and encouraging results that were the foundation of starting an academia-industry collaboration led by UU Innovation - the innovation supporting unit of Uppsala University - in the pursuit of commercialising a new type of battery.

A joint academia-industry commercialisation project

In December 2010 the start-up meeting of the commercialisation project around the new potential battery developed at the Ångström Laboratory was held at *Arlanda Airport* in Stockholm. It was now called the *Salt and Paper Battery Project* (S&PB project) as these were the basic components of the battery; cellulose and a saline solution. The project group attending the meeting consisted of both Swedish and foreign company representatives, a Finnish research institute and academic researchers from Uppsala. The agenda for the day was to discuss how to proceed in the technical development as well as commercialisation of the new material that could be used for a new type of battery solution. The group, led by the innovation supporting unit of Uppsala University - UU Innovation, had just received financing for the next three years from the Nordic Innovations Centre (NICE)[5] for academia-industry collaboration for this particular purpose with the goal of navigating "…*a constellation of institutions and industrial companies active throughout the entire chain from research to production*" (citation from the application to NICE). The goal of these three years was to bring forward a prototype that would be ready for commercialization - i.e. industrial applications. A criteria for receiving funds from NICE was that several Nordic countries were represented in the group, which of course affected which members were selected, but the idea of UU Innovation of how the group was formed was also that together the members should represent knowledge and experiences of 1) how to further develop the material from a scientific and/or technical standpoint, 2) how to identify appropriate uses and products of the new battery and 3) how to manufacture it in an economically viable as well as environmentally friendly way. Therefore, the members represented 1) scientific and expert knowledge on the materials. This was represented by the research group at the Ångström Laboratory as well as the Research Institute of Finland *VTT*, 2) a potential industrial user/customer of the battery. This was represented by the fabric producer *F.O.V Fabrics* in Borås known for its development of the Swedish airbag and with connections to the car manufacturing industry, 3) a supplier of the main component of the battery - algae cellulose. This was represented by the *FMC Corporation* - a global producer and supplier of cellulose and speciality chemicals for different industrial purposes, as well as a company

[5] NICE is a cross-border organisation under the Nordic Council of Ministers for the promotion of economic growth and competitiveness in the Nordic countries. For further information: www.nordicinnovation.org

with knowledge of how to design batteries which was represented by the battery testing and development company *E.T.C Battery and FuelCells Sweden AB* in Gothenburg also working closely with the car manufacturing industry and experiences of setting up pilot production lines for batteries.

The project leader was UU Innovation which would coordinate the members of the project, facilitate communication within the group and also communicate the commercialisation of the project externally in the pursuit of suitable industrial partners. All members of the group, both companies and academia, were also subsidising the commercialisation project so that they would function as *active* members in terms of actively contributing to the commercialisation process from the standpoint of their respective businesses and ongoing activities.

The interpretation of industry and the roles of the commercial partners

For UU Innovation, there were a number of options in relation to an attempt of commercialising the potential battery. One of them was to form a start-up but as the research was still in its infancy it was not considered the optimal course forward at this point. Also, from earlier experience of start-ups it was believed that this option would take focus away from the technical development and the search for appropriate usages of the battery. Instead they wanted to try a different direction. By forming a group consisting of actors from both academic research and relevant industrial environments the idea of UU Innovation was to work with several aspects of the commercialisation concurrently so that the process of finding a use for the new product would be speeded up. Whether this would lead to the forming of a start-up later on was considered a future issue. They had the intention of coordinating scientific research, marketing of the project and the product as well as setting up a pilot production of the new product more or less simultaneously; as these aspects would be dealt with in parallel the commercialisation process would also be accelerated. In this coordinating role the first and main task of UU Innovation was to identify one or several appropriate applications for the technology so that the technical development, marketing and production could advance from that standpoint with the help of an industrial partner, whether it was within the project group or through an 'external' partner. The ambition of facilitating the transition of the new battery from science to industry by handling several issues in parallel shaped the constellation of the project group and the roles of the different actors of the group. Next follows a presentation of the commercial partners of the project and what their intended roles were.

FMC Biopolymers

FMC Biopolymers, a division of the global corporation FMC Corporation, was involved through its units in Philadelphia, US, and in Trondheim, Norway. The work of trying to incorporate the Cladophora algae in cellulose production was mainly done in Philadelphia. Here the project was part of the process development group in the R&D division of FMC Biopolymers, which had been working with this particular alga in collaboration with the research group at Ångström since 2007. The work in relation to the project of developing and commercializing a new battery technology was focused on scaling up the production of the algae cellulose from laboratory to pilot scale while keeping the qualities connected to the surface area of the algae intact. The task of the group at FMC was to supply the S&PB project with cellulose that could be used for research and development purposes, whether it would be used by the researchers at Ångström and VTT or the other commercial partners, ETC and F.O.V. Therefore it was important that the cellulose which they supplied to the project was optimal in relation to the qualities needed for the particular purpose of developing a material with high energy density, i.e. a high surface area. For this purpose it was not possible to start out from the existing large-scale production of algae cellulose which FMC was already involved in, this production was not adjusted to preserve these particular qualities of cellulose. Instead the process development group at

FMC needed to start from laboratory scale in their investigation of what types of equipment and bleach that could be used and then scale up this process. Thus, although FMC was a large-scale producer of algae cellulose and represented the entire supply chain from harvesting of algae to cellulose for different industrial purposes, in relation to the Cladophora algae and the specific needs of developing a material for a new battery technology, there was no such supply chain or production process.

ETC Battery and FuelCells

As a development company involved in battery testing ETC Battery and FuelCells in Gothenburg was by UU Innovation considered a useful partner in testing and developing the new material as part of a commercial product, .i.e. a commercial battery. ETC was founded in 1999 when the production of Tudor Ltd., a large scale battery producer, was transferred to Spain. With an ambition to safeguard the local competence that had developed through a long tradition of battery production, as well as exploiting the internationally renowned research concerning batteries at the local universities, ETC was formed as a small non-profit organization which would act link between academia and industry. Its members represent several Swedish universities (among them Uppsala university), companies (Vattenfall and Göteborgs Energi) and the municipality. ETC owns and/or collaborates with a number of companies. One example is the spin-off company Alelion that produces lithium-based batteries and of which ETC still owns about 10%. There is also collaboration and joint projects with for instance SAAB and Volvo. Their role in the S&PB project was design and laboratory-scale production of battery cells, electrical testing, suggestions for potential applications as well as suggestions for how to set up a pilot production of battery cells. They were also to work together with Motorola in developing a prototype for a remote control based on the new battery technology. In direct connection to the S&PB project the battery testing facility expanded in terms of testing equipment and a new manager of the battery testing centre was hired to handle both the testing activities and the communication with the rest of the project group.

F.O.V Fabrics

F.O.V Fabrics is placed in the heart of the textile production in Sweden - Borås, and has a vertically integrated production of clothing and technical textiles (for the car industry, the military etc.). With 100 employees they manage to produce about eight million square meter advanced fabric per year with the European market as their prime target. About 300-400 of their customers represent less than 1% of the incomes, while about 50 customers order in larger volumes. Two of the largest customers, which represent about 15% and 7% of the incomes respectively, are *Gore* and *Autoliv*. The most famous product developed by F.O.V is the airbag which was launched during the 1980's. The two current owners of the company, which bought it in 2008, have the ambition of continuing product development concerning technical textiles. One product area which they have identified as potentially profitable in the future is that of so called 'smart textiles' where conductive fabrics is one trend. Therefore the owners of F.O.V approached the research group at Ångström when the research results became known to them. A dialogue was initiated and as the opportunity of financing from NICE appeared FOV joined the S&PB project. Their role in the project was dual; they were both to assists in the development of suitable fabric material that could be used as a component in the battery, and identify potential application areas for the battery in terms of technical textiles and clothing. For this purpose F.O.V hired an electro engineer which was to work with the technical aspects of different fabrics both in relation to using it as a component in the battery and as an application. The starting point of the search for fabric suppliers in their established supply network as well as 'outside' was demands from the research group at Ångström related to required qualities of the fabric material. Another issue was which type of coating on the fabrics that could be used for attaching electrodes.

This has been investigated in collaboration with the Swedish School of Textiles. One central issue apart from the technical development aspects of the battery and how it could be made to function in a textile product was the identification of customers for such products. Smart textiles and conductive textiles were and still are very new product areas and there was or is no existing supplier to learn from.

The outcome of the three-year funded project

The foundation for the commercialisation project was the research results made at Ångström related to how a particular material with a high surface area (algae cellulose coated with polypyrrole) could carry electrical charge. While the results had shown that it was possible to charge and discharge this material there was a lot more to find out about *how* this charging and discharging was taking place so that this process could be controlled and optimised for different purposes. To coordinate this continuing research effort and to create a distinct link between the academic research and the commercialization project the Department of Nanotechnology and Function Materials hired an assistant researcher specialized in electron transport. The objective was to do academic research relevant for industrial applications. However, an unanticipated research discovery which put this focus on hold was that the material could not hold the charge and thus discharged quite quickly. How and why this happened was far from obvious. The initial hypothesis was that it was related to how the materials were combined in the battery (how it reacted with the fluid etc.) and that the solution to the problem therefore was to change how the combination was set up. However, further research showed that it was an integral quality of the conducting polymer itself (the polypyrrol); the material degraded as it was being charged which eventually made it discharge. In 2013, and thus by the end of the three-year NICE-funded S&PB project, the research group had reached two important conclusions in relation to this issue. One, in fact *how* the material was degrading, and second, that it was possible to charge the material without degrading it, but there was still no conclusion in regard to how this could be done within the framework of a battery. In the research process of reaching these conclusions, the research group stopped using cellulose from algae as this particular type of cellulose only added to the complexity of trying to learn what was happening with the material and why. Also, in the effort of reaching enough charge of the battery there were difficulties with completely excluding metal components, which was the initial goal. During the three years of the commercialisation project the research generated several PhD projects, publications and is now (2014) the single largest research program of the department in terms of staff and funding. For the particular purpose of doing further research on the basic features of the material the research group has obtained funding through a five year research grant from the *Swedish Foundation for Strategic Research*. During this time they have also established an important relationship with the Finnish research institute - VTT, which have supplied them with essential knowledge of the properties of the material as well as a craftsmanship in handling this type of material in experiments. This has led to several co-publications of the groups at Ångström and VTT.

For the commercial partners the effects of the S&PB project were not as significant in relation to the creation of a new battery. In relation to the research that was and is going on at the Ångström Laboratory, which at present has excluded the Cladophora alga, FMC Biopolymers is no longer a key industrial actor - at least not in relation to this particular project. However, FMC has as a result of the project developed a pilot scale production (form harvesting to production) of this particular alga preserving as much surface areas as possible. As this was interesting to FMC mostly because of the particular qualities of this alga, and not for the production of a new battery, according to the FMC team it will most likely be used for other purposes which is more in accordance with their existing production (pharmaceuticals, food stuff, and agriculture). ETC is presently no longer involved in the research taking place at Ångström. Their collaboration with Motorola is also dormant as the S&PB has not proven itself as a functional battery technology yet. In addition, as the funding of the project came to an end (and as ETC is a non-profit organisation dependent on external funding) the company needed to search for and become involved in other projects. Even though F.O.V Fabrics took own initiative to become involved in the project and hired new personnel for the particular purpose of developing suitable fabrics and identifying both suppliers and customers for conductive textiles, they did not engage any suppliers or customers in the development project, nor did they engage their own production facilities. In their judgement, this was not something they could proceed with until the new technology showed more potential and thus until they could develop knowledge around what type of production adaptations that would be necessary.

By the end of the project UU Innovation changed their strategy from trying to identify just one or a few applications for the salt-and-paper battery to a wider approach of marketing the technology as a platform for developing and commercialising different energy storage solutions. The project changed its name to *Energy Scandinavia* (ENESCA) and in the pursuit of industrial partners UU Innovation, along with central researchers in the Ångström research group, attends international industrial conferences and also markets the project through for instance crowd sourcing for further ideas of how to implement the new technology.

Discussion

One first obvious observation is that the commercialisation effort of UU Innovation and the other project members did not result in the hoped for commercial product, at least not within the framework of the NICE-funded project. The intention of speeding up the commercialisation process by involving commercial partners at an early stage and in this way trying to shape both the research and commercialisation process in particular directions thus did not have the intended effects. The interesting question is of course *why*. To this question there are also some obvious answers, such as "the scientific research was not mature enough", or "three years is too short to create a commercial product" etc. However, such answers, although they might *indicate* what the problems are, do not provide an explanation to why such processes are difficult. In order to make such an analysis from an industrial network perspective, and thus be able to discuss which technical and organizational resources were interacting and in which ways, we first need to classify what type of settings that were involved in this commercialisation effort and through which central resources. By classifying the involved actors from the standpoint of the central technology the following settings can be identified; the *developing setting* is represented by the research group at Ångström (and VTT) as well as ETC, although this actor was considered a "commercial partner". In relation to the resources that ETC involved in the project they would not have been able to become a producing unit for the new battery. Instead they worked with the separate components of the battery in an experimental way and did not have the financial or knowledge resources to set up a pilot production line. Their knowledge was thus connected to developing batteries, not producing them. The *producing setting* is instead represented by FMC Biopolymer which had a large scale production of the (initially) main component of the battery, the algae. They were highly involved in both developing a pilot production line and producing large quantities of the specific alga needed for the project. They also controlled the whole process from harvesting to supplying the alga with the particular surface qualities intact. However, this company can only be considered a supplying company of one of the components of the battery; they did not have the knowledge or the technical production resources to start producing an actual battery on the basis of this component. Lastly, the *using setting* is represented by F.O.V, as well as Motorola which was a developing partner of ETC. F.O.V was involved as a potential user of the battery in terms of incorporating it into textiles. They had knowledge of large-scale production but only in relation to fabrics/textiles and thus they first needed a functioning battery technology in order to start adapting their production processes in relation to this specific technology. As a user, it was hard for them to engage in any development or production activities before the basic features of the new technology (such as basic components and conductive abilities) were established. The same applies for Motorola; in order to start incorporating the battery as a component into their products (a remote control) it would have to be clear how it would interact with the basic components of their products and production processes.

At least two interesting observations can be made from this classification of settings and involved actors and resources. First, for the producing and using settings the constantly developing technology made it difficult to create any real value; the using setting had difficulty engaging their resources in relation to an "unfinished" technology, and the producing setting eventually became non-essential to the continuing development of the battery - the alga cellulose was only complicating the research process. For the academic researchers on the other hand, the research group at Ångström (as well as VTT), the development process was creating a number of benefits; several publications, PhD projects, research collaboration and further funding. Thus, the way in which the technology remained a "research puzzle" was in no way negative for the academic researchers, on the contrary it grew to become the largest project at the department. For the commercial partners on the other hand this made any further investments or technical adaptations inconceivable. Also, the central component of the battery and the project, and to which the producing setting had an established producing structure - the alga, was eventually removed from the research process. This shows how scientific research will often be flexible in terms which research materials and research directions are pursued. Industry and production will however always be locked to particular investment and resources. Second, in this commercialisation effort that was no actor or resources related to the production of batteries. The producing setting could thus not engage in developing or adapting an established production process that could assemble or produce the battery as a whole. Thus, while there surely would have been some challenging adaptation processes had such an actor been involved, now there was no knowledge or technical resources that could be used as a standpoint for such a process.

The role of the innovation supporting unit, UU Innovation, was to facilitate and coordinate the commercialisation effort. However, as the analysis of the interfaces between development, production and use has shown, the influence of such support is very limited when the process depends on the interaction between such different resources (scientific and industrial) and settings which create benefits in essentially different ways. In this case, an industrial partner with production resources related to battery production could however have made a difference.

References

Baraldi, E., Ingemansson, M., Launberg, A. (2014) Controlling the Commercialisation of Science across Inter-organisaitonal Borders: Four Cases from Two Major Swedish Universities, *Journal of Industrial Marketing Management*, special issue Innovation in Business Networks.

Baraldi, E., & Waluszewski, A., 2011, 'Betting on Science or Muddling Through the Network'. Two Universities and One Innovation Commission, *IMP Journal*, Vol. 5, Issue 3, pp. 172-192.

Bower, J. (2003) Business model fashion and the academic spinout firm, *R&D Management*, 33:2, pp. 97-106.

Colombo, M.G. & Grilli, L. (2010) On growth drivers of high-tech start-ups: Exploring the role of founders human capital and venture capital, *Journal of Business Venturing*, 25, pp. 610-626.

Dosi, G. (1982) Technological Paradigms and Technological Trajectories, *Research Policy*, 11:147-162.

Etzkowitz, H. & Webster, A. (1995) Science as Intellectual Property, in Jasanoff, S., Markle, G., Petersen, J., Pinch, T., eds. *Handbook of Science and Technology Studies*, Beverly Hills: Sage Publications.

Feeser, H.R. & Wiilard, G.E, (1990) Founding strategy and performance: a comparison of high and low growth high tech firms. *Strategic Management Journal*, 11:87-98.

Gompers, P.A. & Lerner, J. (2001) *The Money of Invention –How Venture Capital Creates New Wealth*, Boston: Harvard Business School Press.

Gregorio Di, D. & Shane, S. (2003) Why do some universities generate more start-ups than others?, *Research Policy*, 32, pp. 209-227.

Hellman, T. & Puri, M. (2002) Venture capital and the professionalization of start-up firms: empirical evidence, *The Journal of Finance*, LVII, no. 1, pp. 169-197.

Håkansson, H. & Waluszewski, A., eds. (2007) Knowledge and Innovation in Business and Industry – The importance of using others, London: Routledge.

Ingemansson M. (2010) *Success as Science but Burden for Business? On the Difficult Relationship between Scientific Advancement and Innovation,* PhD thesis, Department of Business Studies, Uppsala University.

Ingemansson, M. & Waluszewski, A. (2009) Success in Science and Burden in Business. On the Difficult Relationship between Science as a Developing Setting and Business as a Producer-User Setting. *IMP Journal*, 3:2:20-56

Lerner, J. (2005) The University and the Start-up. Lessons from the Past Two Decades, *Journal of Technology Transfer,* 30:1/2, pp. 49-56.

Locket, A., Siegle, D, Wright, M., Ensley, M.D. (2005) The creation of spin-off firms at public research institutions. Managerial and policy implications, *Research Policy*, 34, pp. 981-993.

Mansfield, E., (1995) Academic Research Underlying Industrial Innovations: Sources, Characteristics and Financing. In *Innovation, Technology and the Economy: The Selected Essays of Edwin Mansfield, vols. I and II*, Brookfield, VT: Edward Elgar Publishing Ltd.

Meyer, M. (2003) Academic entrepreneurs or entrepreneurial academics? Research-based ventures and public support mechanisms, *R&D Management*, 33:2, pp.107-115.

Rider, S. (2009) The Future of the European University: Liberal Democracy or Authoritarian Capitalism?, *Culture Unbound: Journal of Current Cultural Research*, 1: 83-104.

Rosenberg, N. (1982) *Inside the Black Box: Technology and Economics*, Cambridge, UK: Cambridge University Press.

Rosenberg, N. (1994) *Exploring the Black Box- Technology, Economics, and History*, Cambridge University Press: Cambridge, UK.

Rothaermel, F.T., Agung, S.D., Jiang, L. (2007) University entrepreneurship: a taxonomy of the literature, *Industrial and Corporate Change*, 16:4, pp. 691-791.

Rothaermel, F.T. & Thursby, M. Incubator firm failure or graduation?: The role of university linkages, *Research Policy*, 34:7, pp. 1076-1090.

Siegel, D.S.,Waldman, D., Link, A.N. (2003) Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study, *Research Policy,* 32:1, pp. 27–48.

Van de Ven, A., Polley, D., Garud, R., Venkataraman, S. (1999) *The Innovation Journey*, New York: Oxford University Press

Von Hippel, E. (1988) *The Sources of Innovation*, New York: Oxford University Press.