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## **The transformation of science into patented inventions**

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### **Abstract**

This paper presents the results of a grounded theory study of the transformation of scientific discoveries into patented inventions. Using an algebraic interpretive approach, the narratives collected during interviews are analyzed as Bayesian inferences and the developed theory is tested. The findings recast the relationship between science and patents as a process in which the way the transformation of the scientific invention is handled has an effect on the breadth of the patent scope. Unleashing patent scope surplus is dependent on processes related to abstraction and cognitive variety, which can be mobilized by patent experts with both an in-depth understanding of the scientific discovery, due to their educational background in the life sciences, and capabilities within the legal framework for patenting. More specifically, the findings reveal previously unreported aspects of the transformation of academic science into patents, particularly how university scientists take a fragmented approach to the patenting process, while scientists employed in private companies can reap the benefits of close interaction with patenting experts ? experts who potentially can assume responsibility for searching in new directions for solutions if challenges of exploitation with regard to the scientific invention arise.

# **Making Patent Scopes Exceed the Technological Scopes of Scientific Inventions**

## **ABSTRACT**

This paper presents the results of a grounded theory study of the transformation of scientific discoveries into patented inventions. Using an algebraic interpretive approach, the narratives collected during interviews are analyzed as Bayesian inferences and the developed theory is tested. The findings recast the relationship between science and patents as a process in which the way the transformation of the scientific invention is handled has an effect on the breadth of the patent scope. Unleashing patent scope surplus is dependent on processes related to abstraction and cognitive variety, which can be mobilized by patent experts with both an in-depth understanding of the scientific discovery, due to their educational background in the life sciences, and capabilities within the legal framework for patenting. More specifically, the findings reveal previously unreported aspects of the transformation of academic science into patents, particularly how university scientists take a fragmented approach to the patenting process, while scientists employed in private companies can reap the benefits of close interaction with patenting experts – experts who potentially can assume responsibility for searching in new directions for solutions if challenges of exploitation with regard to the scientific invention arise.

## INTRODUCTION

A central debate in innovation literature has been the ways in which science and patents are related as part of an exploitation process. Research suggests that science is used as an input to technologies (Tijssen 2002; Ahuja and Katila 2004). Gittelman and Kogut (2003) and Murray (2002) argue, however, that the relationship between science and patents is not straightforward. In an empirical study, Gittelman and Kogut (2003) find that scientific inventions are not simple inputs to patented inventions and that the value captured from patented inventions seems to follow a different and even conflicting logic than valuable scientific inventions. They conclude that important science does not always transform into valuable patents and that valuable patents are not necessarily based on important science (Gittelman and Kogut 2003). Murray (2002) examines pairs of patents and scientific papers and finds that distinctive scientific and technological networks exist in which there is evidence of overlap in licensing, founding, and advising but not in citations and co-publishing. This expands the evidence that the commercialization of scientific inventions does not take place through a simple translation of science into a patent. To fully understand the process, we must address important questions, a core issue of which is the relationship between scientific discoveries and patented inventions. With the aim of filling this gap in the literature, this paper focuses on an analysis of the processes of this transformation and asks the two-part question: How is science transformed into patents, and how is it possible for valuable patents to be created on the basis of less important science? One approach to disentangling this gap in the literature is to explore the micro-foundations of what happens when scientists make new scientific discoveries that are transformed into patented inventions and to analyze the elements of the actual transformation process. This is the aim of this research.

One stream of recent literature argues that micro-foundations are a core instrument for understanding organizational performance in dynamic environments. However, the exploration of micro-foundations in management studies is still in its infancy; therefore, it has been argued that significant gaps still need to be filled to improve our understanding of organizational performance (Gavetti 2005; Teece 2007; Abell, Felin et al. 2008; Zahra and Wright 2011), this is certainly also the case for understanding how organizations perform in transforming scientific discoveries into patented inventions. Even though no micro-foundations for this specific transformation process have been examined, there are recent literatures from which we can draw upon when constructing the micro-foundation mechanisms derived when analyzing our data. In a recent paper by Eisenhardt, Furr et al. (2010) they theorize that three cognitive mechanisms giving a solitary approach to navigating and prescribing solutions in dynamic environments in reaching a balance between flexibility and efficiency. Furthermore, the handling of conflicting agendas has been shown to be a core mechanism in achieving high performance (Brown and Eisenhardt 1997; He and Wong 2004; Smith and Tushman 2005). The three micro-foundations presented by Eisenhardt, Furr et al. (2010) are abstraction, cognitive variety, and interruption; these elements are constructed on the basis of their origins in the cognitive psychology literature (Schwartz 1978; Lachman, Lachman et al. 1979; Barber 1988). See Armstrong, Cools et al. (2012) for a recent literature review on cognitive psychology in management, which, however, the three micro-foundation mechanisms has not yet been unfolded in an empirical setting of the innovation process.

Transforming a scientific discovery into a patented invention is likely to involve conflicting agendas; the networks playing a role in the transformation process overlap each other and there are many different stakeholders in the process (Murray 2002), who have different motivations and goals. Venture capitalists influence the chosen exploitation strategy in certain directions (Hsu 2006) whereas scientists may be oriented towards their research, as they are

ready to pay by accepting a lower wage to be scientists with preferences for their own scientific research (Stern 2004). Therefore, the scientists might not be able to abstract from the scientific invention they have created and mobilize actions to understand how the scientific invention should be transformed into a valuable patented invention, taking into account the market and technological landscape of opportunities and limitations. In the face of these challenges, how are valuable patented inventions created that exceed the technological scope of the initial scientific discovery? One part of the answer may be revealed by examining the role of a set of actors who are often overlooked in innovation literature: the patent experts, the experts who are in charge of creating, defining, and formulating the patented invention. Prior research has aimed at linking patents directly to the characteristics of the inventors behind the invention (Zucker, Darby et al. 2002; Gittelman and Kogut 2003; Giuri, Mariani et al. 2007) rather than considering the patent as something that is created on the basis of a transformation of the scientific invention developed by a scientist (inventor); a scientific invention that, to become a patented invention, goes through a transformation process that is orchestrated mainly by patent experts. The transformation process involves positioning and developing the scientific invention into the broadest possible technological scope in the patent landscape (patent scope), to secure the freedom to operate in relation to future developments and potentially to identify technological applications and ways of exploitation that were not originally part of the scientific invention created by the inventor.

The current study addresses this gap in the literature by utilizing a grounded theory building approach (Eisenhardt 1989; Strauss and Corbin 1990). I examine the question of how patent experts influence patent scope to exceed the technological scope originally identified by the scientist by using sequence analysis (Abbott 1995) combined with an algebraic data analysis method in which the narratives of the sequence are examined as Bayesian narratives in a Boolean structure (Abell 2009). This provides detailed case studies of the creation of twelve

patented inventions spurred by scientific discoveries taking place in three separate innovation processes. I found that the patented outcome, the patent scope, can be defined in three dimensions: below expected technological scope, expected technological scope or exceeding technological scope. Below expected technological scope refers to those patented inventions for which the patent simply does not protect the invention. This situation arises most often when the patent application covers only parts of the scientific invention. An example could be a patent for a treatment for both anxiety and depression that only includes the indication of depression. Expected technological scope refers to situations where a patent application covers the scientific invention created by the scientist (nothing more or less), while exceeding technological scope covers patent applications in which the protection exceeds the initial scientific invention. An example of this could be that the initial invention might only be for one type of, for example, sulfur with a certain effect, but during discussions (and perhaps additional work in the lab initiated by the discussions) a patent application for all types of sulfur is established, potentially giving rights to a much larger scope of technological protection from which the patent holder can benefit. Even though this is a small N study of the transformation of twelve science patent transformations, it became clear that the ways in which a patent application can be created in order to exceed the technology scope of a scientific invention vary, as the complexity of technologies leaves great room for creativity, argumentation, and discretion.

The drivers of these three types of patent scope (below, expected, exceeding) are distinct, yet patent experts play a critical role in each. Expected technological scope is realized when patent experts are included in the process in due time, ensuring an interruption of the scientific research process. In an innovation process in which scientists manage the process of engaging patent experts, the interruption can simply be forgotten or omitted because the scientists do not wish to patent the invention or because they are unaware of how to identify

patentable elements in scientific development processes. Below expected scope is realized when the interruption does not occur in due time or because of simple mistakes. Exceeding technological scope calls for patent experts to perform mobilizing actions, applying cognitive variety and abstraction to the process. Patent experts are uniquely qualified to do this because they have a deep understanding of the scientific invention and at the same time, they understand the opportunities that the patent system and patent landscape offer and can make recommendations as to the exceeding potential of the scientific invention. Together these findings recast the relationship between science and patents as a process in which the way the transformation of the scientific invention is handled has an effect on the technological scope of the patented invention created. To unleash the greatest possible technological scope, the invention process must incorporate certain developments. First, an interruption needs to take place. Second, the patent expert must have time to investigate the potential for greater patent scope. Third, iterations between scientists and patent experts are needed in order to unlock the potential, including actions to mobilize the effects of abstraction and cognitive variety, which have been identified as being of key importance to patent scope.

This view of the transformation of science into patented inventions has implications for theories of innovation. Findings that suggest that science is used as an input to technologies (Tijssen 2002; Ahuja and Katila 2004) are confirmed. However, while organizational literature has highlighted the necessity of an exploitative and explorative organizational nature to create high performing firms (March 1991), I highlight the micro-foundations for which better performance is conducted in the process of transforming science into patented inventions, and extend the literature to propose a specific relationship between science and patents in terms of technological scope.

The paper proceeds as follows: First, I describe the theory building, using the multiple case study method, based on sequence studies, semi-structured interviews, observation studies and

secondary data collection. I describe the research sample, the data collected, and the analytical techniques on the basis of the Bayesian inferences used in combination with the grounded theory approach. I then review the findings that emerged from the data analysis and their implications for understanding the transformation of science into patented inventions. I conclude by discussing the broader implications of this study for understanding the micro-foundations of the transformation of science into patented inventions.

## **METHODS**

The research design I use in this study is grounded theory building (Eisenhardt 1989; Strauss and Corbin 1990) combined with an algebraic and mathematical approach to narrative data analyses argued by Abell (2009). I have selected the grounded theory approach because of the lack of prior theory and research on the role of iterations between scientists and patent experts in the transformation of scientific discoveries into patented inventions. The setting was the pharmaceutical industry, as the pharmaceutical industry is a leader in terms of systematic commercialization of scientific discoveries (Cohen et al. 2002; Klevorick et al. 1995). I used a multiple case study in order to allow for ‘replication logic’. I therefore treated each of the scientific discoveries that had been transformed into a patented invention as a series of experiments, with each of the transformations serving to confirm or disconfirm the inferences drawn from the other cases (Yin 1989). In this approach, the findings are deeply grounded in varied and empirical evidence, which makes the results more valid and generalizable than those of single-case studies (Eisenhardt and Graebner 2007).

The study design involved twelve transformations of science into patented inventions (see Table 1). In order to increase generalizability, the twelve scientific discoveries were divided between five conducted at a university and seven at a private firm. Prior research has suggested that timing in R&D influences the degree to which new technologies are based on



science: early in the process there is an emphasis on science-based discoveries, whereas in the latter stages of R&D, there is increasing emphasis on technological knowledge (Cassiman et al. 2010; Iansiti and West 1999). To create generalizable findings with respect to timing in the R&D process, the sample therefore included three innovation processes that had been ongoing for about a decade, during which several scientific discoveries had been made. In order to avoid the likelihood of respondents having a misperception of the innovation processes due to extreme success or failure, only active innovation projects yet to be commercialized (or closed down) at the time of interviewing were chosen. At the same time, only R&D projects for which respondents from early stages of the process, some dating back 15 years, were available for interviews were selected. This allowed the research to include both retrospective and concurrent data, which allowed an in-depth exploration of how the innovation process had evolved over time (Leonard-Barton 1990). Furthermore, as the innovation process was still ongoing, the development of the projects was fresh in the minds of the interviewees when the interviews were conducted.

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Insert Table 1 about here  
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Respondents included both the scientists behind the inventions, the patent experts engaged in the transformation process, and other stakeholders in the drug development teams, such as project managers, clinicians, regulatory personnel, marketing personnel, biostatisticians, technology transfer officers, and R&D managers. Respondents were identified through pyramiding (Von Hippel 2009; Poetz and Prugl 2010).

## **Data collection**

In the below section I describe each of the processes of data collection and data analysis separately, even though the processes appeared simultaneously. Initial interviews concerning the phenomena studied started in the summer of 2009 and the final data collection was done

in the beginning of 2013. An extensive research protocol describing this process in detail is available upon request, explicitly showing how this study uses a grounded theory approach as main method, performed while relying on strong elements of abduction (Peirce 1903) hereunder sequence analysis, selected approaches to observations studies as well as semi-structured interviewing and questioning on the basis of scales, and an algebraic methodology to further challenge my own understanding of the conclusion in the constructs presented. This approach of combining the different approaches follows Eisenhardt (1989) suggestion for how to strengthen grounded theory building, by applying multiple data collection and combine both qualitative and quantitative data.

For this research I used three main sources of data: 1) the interviews with scientists, patent experts, and other stakeholders in the innovation processes under study, 2) participation in innovation process meetings, and 3) archival data, both public and non-public, hereunder patents, scientific publications, and other material provided by respondents. The primary source of data was more than 50 interviews as well as observations from more than 30 internal meetings. During some time periods (>1year) I was present once a week at the sources of the data collection. Initially, the selection of suitable innovation projects was done in the following manner: The two innovation processes at the firm were selected on the basis of observation studies and interviews about more than twelve innovation projects in the firm, whereas the scientific inventions created at the university were selected due to the focal professor and inventor having received prizes for an innovative mindset and for being highly active in patenting.

For the sequence analysis the initial process involved establishing a chronology of events, which I did for each of the three innovation processes separately. Data regarding the chronology of events were gathered by attending project meetings held from the winter of 2009 until May 2010, as well as during the period of Summer 2011 to Fall 2012, by reading

project material, such as minutes from earlier meetings, by interviewing key stakeholders, and by accessing public data, such as scientific publications as well as patent data. During the selection process of the events that constituted the chronology to be presented in the case study, a theoretical sampling was conducted, focus was on events that were related to the following: a) a change of direction in the innovation and/or product scope and b) patent initiatives, such as patent applications and changes in the patent filing focus. The preliminary chronology of the events collected took a form in which E indicates a point in time. For each of the events investigated, a range of different actions ( $A_n$ ) leads to a certain event ( $E_n$ ) occurring in a certain context ( $C_1$ ). The actions are not necessarily time constrained and the context changes over time. See the chronology of events in Figure 1, 2 and 3.

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Insert Figure 1, 2 & 3 about here  
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To identify the actions ( $A_n$ ) leading to the events ( $E_n$ ) happening in a certain context ( $C_1$ ), interviews were made with stakeholders of the innovation process in the three cases. The questions raised during the interviews were grouped into five different categories (see the interview guidelines in Appendix 1). First, to focus on the chronology of events, interviewees were asked if the chronology of events presented was in consensus with their understanding of the innovation process. Or did they have a different opinion, for example, with regard to the events that were important for the innovation process? Second, narratives were gathered that focused on the actions leading to each event. Third, prior research on counterfactuals has shown that counterfactual statements are particularly beneficial for understanding a perceived cause of an outcome (Mandel and Lehman 1996; Roese 1997); therefore, there is a focus on counterfactuals in this third step of the interview. Fourth, to secure information on the competencies and roles of the stakeholders in the process, questions on different innovation stakeholder capabilities were raised, with strong focus on the transformation process. Fifth, to

provide a context for how the interviewee assesses the importance of the different events in the process the final questions concerned the respondent's perception of the innovation process as a whole. To prepare for each of the interviews, I reviewed my notes from prior interviews.

The interviews about the university scientific discoveries were recorded and transcribed. In the case of the firm, the information received during the interviews was very sensitive as it dealt with potentially highly profitable drugs still under development. Therefore, the firm did not give permission to record the interviews and I instead had to make extensive notes, often asking the respondent to wait while I wrote down a quote in an anonymous format, removing specific details about, for example, indications, substances, compounds, diseases, persons, firms, and cooperators. The quotes were subsequently checked by the firm to ensure the level of anonymity demanded. Some respondents, often key stakeholders, were interviewed several times – some more than five times - in order to clarify quotes or to gain further insight.

Prior to the main data collection effort, I conducted nine pilot interviews to gain preliminary insights into the transformation process that I wanted to study, to identify an appropriate method for gaining access to highly sensitive knowledge, and to test the more general questions of the interview guide. The pilot interviews were held with university scientists, biotech entrepreneurs, R&D managers, patent engineers in biotech firms, and external patent engineers.

## **Data analysis**

The overall methodological approach to the data analyses follows prior studies: initially, I analyzed each individual case and thereafter compared cases to construct a conceptual framework (Eisenhardt 1989), doing both within-case and cross-case analyses (Miles and Huberman, 1984). When analyzing each case, I focused on generating constructs of the

transformation from science to patented invention to understand how it had been effectuated in each case. This required an iterative process of refining questions and revisiting respondents. In this way, quotes relating to how each action led one event to the next were collected and examined.

During this process I was led by going deeper and deeper into understanding how the narratives presented established evidence for this links presented, in order to understand the reasoning behind certain actions that had been taken and the results here from, being either below, expected or exceeding patent scope. The latter part of the interview guide also showed very important as interviewees in this part had given really clear indications on the construction of the reality, whom that was important, based on which capabilities they identified as important, and their frustrations or happiness with different cases, even within the same innovation processes, gave great insights as to the complex nature of transforming scientific discovery into patented inventions. Especially also this latter part of the interview resulted in putting extra focus on the patent experts as mobilizing agents in creating exceeding patent scope. After establishing my own constructs of the data, based on strong links to micro-foundation and cognitive psychology literature I initiated a assessment process with other lenses to generate further insights, and ultimately confirm or disconfirm my the hypothesized relationships.

Therefore when each innovation process, exemplified by two to five cases, had been finalized, I initiated an algebraic data analysis process based on sequence analysis. Sequence analysis is widely applied in a large range of research areas, such as psychology, economics, archeology, linguistics, political science, and sociology (Abbott 1995). Sequences have four distinct characteristics: 1) sequences can be distinct or unique, 2) sequences can be dependent between their states, 3) there can be varying degrees of dependence between sequences, and 4) sequences can be analyzed as both independent and dependent variables (Abbott 1995). Of

the two distinct methods of sequence analysis that have been pursued in the literature, I chose to focus on analyzing actual data as opposed to simulated data. The reason for this choice was my aim to examine the R&D process over time as well as to use real life examples to deepen the qualitative understanding of the transformation process. By doing so, I aimed to supplement the immense number of studies examining determinants of patenting/innovation by providing in-depth insights into how patents are created. The core of this study is to identify the micro-foundations of the patterns in the sequences of iterations between scientists and patent experts, seen over the total sequence of data, within parts of the sequences in the data, or across the innovation projects. This opens up for the choice of either making the patterns seen in the sequences the explained variables, to understand where they come from, or of making them the explanatory variables, that is, the determinants of the future.

### **Small N, Narratives and causal inferences**

Eisenhardt (1989) suggests that utilizing cross-case pattern search by applying divergent techniques, is appropriate in order to ensure that the investigator “*look beyond the initial impressions and see evidence through multiple lenses*” (p.533) As this case study is utilizing narratives as evidence the algebraic and mathematical approach argued for by Abell (2009) has been chosen as supporting technique to analyze evidence presented through several lenses . With point of departure in this method, the quotes are studied as Bayesian inferences generating Bayesian narratives, and the results are multiplied according to a Boolean structure (Abell 2009). This means that besides using the twelve case studies to develop a theory of transforming scientific inventions into patented inventions, I also use them to examine causal inferences. The reason for the chosen approach is that the transformation process studied in this research is a highly complex phenomenon, as well as a very sensitive topic. It would therefore not be possible to test the theory proposed using large N studies. Below, a brief

introduction to the reasoning behind the data analysis method is presented; for an in-depth explanation see Abell (2009).

Narratives (developed as sequence studies) can be structured as presentations of evidence for each linkage in an event study. For example, if we have two events, E1 and E2, then a narrative (b) collected to explain the actions (A1) that demonstrate a linkage between E1 and E2 can be analyzed as evidence for the causal link between E1 and E2. For example, if one statement (b), presented as an explanation of (A1), is proposed as evidence for the causal linkage between E1 and E2, then in accordance to Bayes' Law, the probability of the causal inference would be:  $P(b) \cdot P(A|b) = P(b) \cdot P(b|A)$  and

$$P(b) \cdot P(\neg A|b) = P(\neg A) \cdot P(b|\neg A)$$

where  $P(A)$  is the probability of A,  $P(b)$  is the probability of b, and  $P(b|A)$  is the probability of b given A, and  $P(b|\neg A)$  is the probability of b given  $\neg A$ . Furthermore, based on Good (1983):  $\log L_b = \log \text{odds}((A:\neg A)|b) - \log \text{odds}(A:\neg A)$

it is possible to provide a measure of evidence b in support of the causal link A. If more than one piece of evidence (b) is present, the probability of  $L_b$  is found by multiplying the odds ratios of each item, which for n items of evidence can be expressed as:

$$L_b = L_{b1} \cdot L_{b2/b1} \cdot L_{b3/b2 \cdot b1} \cdot \dots \cdot L_{bn/b1 \cdot b2 \cdot \dots \cdot b(n-1)}$$

In practice, this means that if a number of assessments of each quote (b) are obtained, the likelihood of a causal inference (A) can be estimated. In line with the approach suggested by Abell (2009), I therefore had a number of jury members assess the likelihood ratios for each piece of evidence (b) linked to a certain causal inference (A). The results are presented in Tables 2 and 3. In tests of the practical implementation of the method I experienced that the jury members had problems in utilizing infinite numbers, the jury member was therefore

initially asked “Do you find that this first piece of evidence (b) 1) supports, 2) contradicts or 3) neither supports or contradicts the hypothesized relationship between  $E(n)$  and  $E(n+1)$ ?” If respondent’s answered supports, they got the following question “now please also estimate with what likelihood ratio you find that the evidence supports the hypothesized link, using 2 if you find that the piece of evidence makes the hypothesized relationship a little bit more likely or you could write 10 in the brackets if you find that the piece of evidence supports the hypothesized relationship in such a way that the causal relationship is virtually certain. Any other number in between can of course also be used – depending on which likelihood ratio you find as being accurate for this piece of evidence.”

For this research, a jury of four members was assigned to each innovation process: two stakeholders in the transformation process being examined and two management PhD candidates who did not know the cases, events, narratives, or evidence beforehand. The constitution of the jury made it possible to analyze whether being a stakeholder influences the jury members’ estimations of probative force. The jury was given explicit guidelines on how to assign likelihoods. The actual process entailed a number of steps. First, I introduced the jury to the research topic. Second, the jury members’ assignment of likelihood ratios in the perspective of the research was outlined. Third, in response to the difficulties jury members experienced in assigning likelihoods without an example during pilot tests, an example was implemented in the data collection. Fourth, the context of the case was introduced. Fifth, the entire innovation process, including all actions ( $A_n$ ) and events ( $E_n$ ), was introduced together with the ‘evidence’ (b) connected with it. Most often there were several items of evidence (both counterfactuals and other narratives:  $b_1$ ,  $b_2$ ,  $b_3$  etc.) to present to the jury members. Finally, the jury was asked to estimate the probative force of each piece of evidence in respect



to the hypothesis presented. Thus, each jury member analyzed each piece of evidence (b) and assigned it a likelihood ratio.

The example in Tables 2 and 3 below presents an overview of how the results of the jury were analyzed; here, an overview of the results of six actions (A1, A2, A3, A4, A5, and A6) based on 23 pieces of evidence (b<sub>1</sub>, b<sub>2</sub>, b<sub>3</sub> etc) are presented. In total, 42 relationships (A) were investigated with more than 180 pieces of evidence (b). Each hypothesized relationship was assessed by analyzing the results of the likelihood ratios for each of the pieces of evidence; between two to five pieces of evidence belonged to each relationship. In Tables 2 and 3, jury members 1 and 2 were the PhD candidates and jury members 3 and 4 were representatives of the innovation process. The results presented in Table 2 show the likelihood ratios of the hypothesized relationships. A closer examination of the data shows that 14 out of 23 quotes were assessed by at least one jury member to justify the causal links presented beyond all reasonable doubt (b=10), divided as follows: eight quotes by one jury member, five quotes by two jury members and one quote by three jury members. Eight out of 23 quotes are not assessed by any jury members as being supportive or contradictive beyond all reasonable doubt. Eleven out of 23 quotes were not assessed by any jury members as being neither supportive nor contradictive. All of the 23 quotes were assessed to be supportive to some degree. In addition, the differences between the types of stakeholders in the innovation process were analyzed. The patent expert who had been part of the innovation process (Expert 3) made a higher average assessment of likelihoods than the three other jury members. Furthermore, the jury members from the firm made higher assessments than the external jury (PhD candidates). The external jury members selected the assessment value of “1” (neither supportive nor contradictive) much more often than the internal experts (see Table 3).

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Insert Tables 2 & 3 about here  
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In addition to analyzing the data using an algebraic method, I also carefully analyzed the data with respect to the three micro-foundations.

### **Patent performance – patent scope**

Prior research by economists and policy makers has often used patents as a measure of innovation activity simply by counting the number of patents or using the value of the individual patent as measured by a variety of indicators, of which forward citations, family size and oppositions, or a weighted sum of several indicators (Lanjouw and Schankerman 1999) have been argued to be the most precise (Dietmar Harhoff, Frederic M Scherer et al. 2003). However, the task of assessing the value of individual patents has proven difficult, especially due to a highly skewed distribution (Scherer 1965; Griliches 1990). In contrast to the empirical work, the theoretical patent literature in economics has mainly focused on two different measures as determinants of patent value: patent length (William Nordhaus 1969; Scherer 1972) and patent scope or ‘breadth’ (Gilbert and Shapiro 1990; Klemperer 1990; Scotchmer 2004). The main arguments presented in the literature on patent scope advocate that the broader the patent scope (the technological scope of protection), the higher the number of competing products and processes that will infringe the patent; therefore, a higher value will be associated with broader patents (Gilbert and Shapiro 1990; Merges and Nelson 1990). On the basis of the same arguments, empirical studies have used IPC codes in patents as measures of technology scope (Lerner 1994). Lerner (1994) found a correlation between the number of IPC codes (the measure utilized for patent scope) and the value of patents in the biotechnology industry. However, these results might have been specific to the biotech industry, as they have not been confirmed in other empirical studies (Lanjouw J.O. and Schankerman M. 1997; Dietmar Harhoff, Frederic M Scherer et al. 2003), which also indicates that the notion of patent scope is too complex to be measured by counting IPC codes.

Merges and Nelson (1990) describe some of the elements in understanding the complexity of patent scope: patent scope is linked to both the decision process concerning claims handled by (national) patent offices, which take into account the local legal principles as well as the individual invention proposed by the applicant. The individual invention proposed in the claims of the patent application provides the greatest opportunity for increased value (increase in patent scope) for patent applicants and also for the variance on which we base the outcome variable in this study. The technological scope of a patent is an important measure of the value of the patent, and creating a broader scope in a patented invention than what was presented by the inventor in terms of the scientific invention on which it is based can have a great impact on the commercial reality of the patented invention – if the inventor has the freedom to operate and can reap the potential benefits of having the right to prevent others from commercially exploiting a certain technological scope.

A gap in the patent innovation literature is therefore understanding how the creation of patent scope is influenced by the micro-foundations of the process of transforming the scientific invention into a patented invention and highlighting how this outcome can be more accurately conceptualized in terms of the three distinct dimensions previously noted, each of which exemplifies degrees of patent scope in relation to the expected scope of the scientific invention: 1) below expected scope, 2) expected scope, or 3) exceeding scope.

Such an evaluation of patent scope can only be performed by experts with in-depth knowledge of general patenting opportunities as well as very specific knowledge of the transformation of the case (the scientific discovery and the patented invention) being examined. Therefore, to utilize such an approach to evaluating the performance of the individual patent applications, I asked for the assessment of people who had been part of the innovation processes, such as the scientists and patent engineers. They were asked to evaluate each patent application in relation to the invention upon which it was based. They were

introduced to the full series of events, including several cases of scientific inventions related to specified patent applications, and were then asked to assess whether the invention was based on basic or applied science and to what degree the technological scope of the patent is below, expected or exceeds the scope of the scientific invention. See Appendix 3 for the assessment questionnaire. Furthermore, to understand the reasons behind respondents' answers in each of the categories, they were asked write their answers in an open format. A pilot test showed that the respondents did not take long to answer the questions; they could easily follow the reasoning of the assignment and often they had an assessment of the patent in relation to the prior scientific invention without even seeing the abstract of the patent, but only being told the year or the name of the patent application. This indicates that this approach to understanding patent scope and the extent to which it resembled the scientific invention seemed logical to the respondents. Results of the assessments of the individual patents are presented in Table 4.

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Insert Table 4 about here  
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The distribution of the patent scope assessments varies, out of the 12 patents applied, 5 patents exceeded scope, 3 from firm and two belonging to the university. No patents from the firm were assessed as below patent scope, whereas two patents from the university were. Timing in the R&D phase matters, in each of the three innovation processes examined the initial patents received exceeding scope (#1, #6 and #12), however, also later patents did exceed patent scope (#3 & #7). All patents were assessed as being based on applied science.

## **MAKING PATENTS SCOPE EXCEED THE TECHNOLOGICAL SCOPE OF THE SCIENTIFIC INVENTIONS**

Why did some transformation processes from scientific discoveries to patented inventions create new value in the form of extended patent scope whereas others did not? While prior research has focused on the role that scientists play in generating valuable patented inventions (Zucker, Darby et al. 2002; Gittelman and Kogut 2003; Giuri, Mariani et al. 2007), this study found that patent experts play a critical role in generating a patent in which the patent scope exceeds the technological scope of the scientific invention. These experts contribute to the generation of patent scope by mobilizing actions that can be characterized as interruption, cognitive variety, and abstraction that are then collectively performed in the teams. With these types of actions the innovation process remains focused on balancing flexibility and efficiency in reaching commercialization by securing the freedom to operate and to ensure that the patented invention can attain a position in the patent landscape from which the inventor can benefit.

The three distinct mechanism identified during the grounded theory process have been discussed prior in literature, both separately in cognitively psychology literature, but also as three main micro-foundations by which managers can control the tension between efficiency and flexibility in dynamic organizations (Eisenhardt, Furr et al. 2010). This approach to organizing offer a solitary solution to achieve a balance between flexibility and efficiency as opposed to the dual solutions proposed in the ambidextrous approach (Tushman and Oreilly 1996; Adler, Goldoftas et al. 1999; He and Wong 2004) see also the Organization Science 2009 (Jul-Aug) special issue on ambidexterity. In this research I suggests that the work with patent scope, and reaching exceeding patent scope, can be viewed in the framework of flexibility and efficiency, exceeding patent scope offers a flexibility in terms of future freedom to operate, as well as, enable a patent protection which will be adequate to

appropriate returns if a future product launch based on the scientific invention should be accomplished. Additionally efficiency can be closely linked to the freedom to operate envisioned in the process of creating exceeding patent scope, most importantly creating a clear vision of the potential ‘minefields’ (in terms of patents the inventor would infringe in a future) that needs to be navigated around during the R&D process, can ensure that the inventor identifies ways to circumvent them upfront instead of later after time consuming and expensive innovation processes have been conducted. This might be more important for scientific inventions created in firms, as opposed to inventions originating from universities, due to research exemptions (or also named the safe harbor exemption, see for example in the US § 271(e)(1) exemption/ Hatch-Waxman exemption, or in EU included in the EC Directives 2001/82/EC) which means that scientists is allowed to perform tests and research despite 3<sup>rd</sup> party owning patent rights covering the technology. However, as universities are engaged in patenting to make deals with businesses which shall carry the inventions forward, the principals also apply to them.

### **Interruption**

The drivers of technological scope are distinct, yet patent experts play a critical role in each of them. Expected technological scope is realized when patent experts are included in the process in due time, ensuring that an interruption of the scientific research is made. The effect of interruption upon flexibility and efficiency was described by Eisenhardt, Furr et.al as *“Interruption enables flexibility because it creates a pause in the flow of activity that can trigger reassessment and change of direction. Yet interruption simultaneously allows for efficiency because it also enables leaders to avoid wasting time on inappropriate paths.”* (p.1269). Following this approach I reflect on the effects of interruption on the patenting scope, as any moment where the team involved in patenting takes a step back to reassess what the patent scope should be. These interruptions are identified both in the events of the case

studies, in the narratives evidencing the linkages of the different events, and in the more general assessments of interruption done by the interviewees.

In an experimental study Okhuysen and Eisenhardt (2002) identified interruption as a significant mechanism to increase performance of both novel and ambiguous assignments, performance was increased both in terms of creating flexibility and efficiency. However, in other studies in management, in which interruption has been examined by applying another unit of analysis, the individual persons, results have shown differently: Attributed to the same effect, Tushman and Rosenkopf (1996) examined how CEO succession influenced performance, they found a positive effect in a stable context, but a negative effect on performance in turbulent contexts. Another study of top management, also associated with interruption, identified that movement of top managers across organizations resulted in subsequent changes in product-market entries, and the effects was moderated by the experience. In this study a range of types of interruptions are examined, one example being a patent expert being assigned to identify a new way of patent protecting substance  $X_1$  against disease  $Z_1$ , if product should be brought to market (see t12 in Figure 2), a patent application should entail an inventive step, novelty and industrial applicability, why the patent experts assignment could be translated into creating (with input from team members) a new invention. In this process the interruption was initiated by management, the reason for management to initiate the process was that the lifetime (20years) of the patents applied protecting the invention early in R&D was running out. This meant that the current invention could not be protected against generics or competitors other than the possibilities that the data exclusivity gives (time period varies, in US 5 years for pharmaceutical chemical entities, in EU 8 years, and Japan 6 years). During the interruption, the patent expert interviews innovation project stakeholders to identify how the scientific invention created could be further developed in order to hand in further patent applications to create new patent protection. The patent expert

handling the process explained the interruption as: *"I talked to many different persons, several persons had really good ideas, some of the ideas was old ideas that we have implemented now, and some new ideas. There was surprisingly a lot of information which needed to be shared in the organization, so it was a really good catch"*

During the interruption innovation project members also met and discussed the ideas generated. The innovation project team member describes the meeting: *"At the meeting (E15) it was kind of a health check on the ideas that was gathered during the interviews (E14), but new ideas was also generated"* and *"During E15 we had ideas generated which we together build to be a sort of realization, then we could see the future perspectives of things (E16)"*

However, while the process – having an interruption mobilized by the patent expert - provided evidence for project team members to enable them to identify direction for the future, and even come up with three inventions which could be patented, the chemist explained the scope of which the discussions had been made:

*"The chemical considerations the patent expert had made contained identifying IP opportunities in the chemical structure, IP opportunities in the production and process considerations and so on, it means that the ideas are more of a defensive character. They did not influence the chemical structure of the innovation it was more to keep the others away"*

The description and assessment of the patents created as results from this interruption (patent #8,#9 & #10), also showed to be very narrowly identified (see comments in Table 4). In formal terms, this finding suggests the following relationship:

Hyp 1; Patented inventions will be more likely to achieve expected technological scope if patent experts perform 'interruption' during the transformation phase from scientific invention to patented invention.



At the same time, one should remember that in the absence of interruption there would not even have been any new inventions to apply for. In the above example the interruption was initiated by management, however, mobilized by patent expert, as one stakeholder to the process explains *"The patent experts needed to live up to his management's expectations, I think that is why he needed to find alternative IP routes"*. The chosen approach from patent expert was beyond the formal structures of the firm, as the patent expert explains: *"How do we organize this process? It was my colleagues' idea to interview all stakeholders of the project prior the meeting. This was a very good idea this removed the pressure as everybody had the opportunity to say what they wanted on beforehand. And then I could structure the results from the interviews in a way which we could use at the meeting. The above statements identify the patent expert as a main driver in the interruption taking place when transforming a scientific invention into a patent in an innovation process at a firm. This was not the case at the university, the professor explains: "Here the interaction with TTO (Tech Transfer Office) happen ad-hoc or actually it is not present, we never see our contact person, there is no work internally in the organization (referring to the tech transfer office mainly conducting external to the university activities). They (TTO) never come here, they do not make any arrangements for us, nothing happens. It is like we do not exist, only when we send them an invention disclosure, or else we do not exist. And that even though we are a group of scientists where there have been several discoveries, it would have suited if they had come to visit occasionally."*

In literature it is described how structures in organizations improves reliability of actions, whereas less structure provides more room to take unintended actions (Gibson and Birkinshaw 2004), the literature therefore calls for moderate structures to increase performance (Galunic and Eisenhardt 1996; Tripsas 1997; Gilbert 2005). This study suggests that the relationship between structure and interruption is to some extent parallel in

occurrence. In situations, as at the university, lack of interruption (or structure ensuring visit by TTO) resulted in no patents being applied for. The scientist behind the scientific inventions created which did not get transformed into a patent explains it the following way: “Then we did the tests, and the first time we tried it we saw that it was a general tendency, then we also tried other markers. It was extremely interesting. However, we could not patent it, because of prior art, or maybe we could actually have patented it, if we had known more about patenting *then, but that was not something we knew at that point*”. The scientist refers to results prior E2. The patent expert, who participated in this case, was an external patent expert hired by the TTO office, however, communicating directly with the scientists explained the situation the following way: “*The process is, that the scientists comes very late. I do not recall that we had an interaction, in which we sat down and planned. The scientist came as a sorcerer out of a box and told that ‘now this invention had been made, and by the way I should be at a conference in 14 days’.* So there was no red thread in the process. It was all led by when the scientists thought it was time. And always in last minute – so you just throw everything you have in your hands and start to *put things together.*”

In an innovation process in which scientists manage the process of engaging patent experts, the interruption can simply be forgotten or omitted due to a lack of interest in patenting or a lack of wisdom about how to identify patentable elements in scientific developments. In formal terms, this finding suggests the following relationship:

Hyp 2; Patented inventions will be more likely to perform below expected technological scope or even result in no patents at all, if no structure dictates patent experts to mobilize an interruption as part of the innovation process.

## Cognitive Variety

While cognitive variety to some extent in practical interpretation covers interruption, there are distinct differences. A main argument in cognitive psychology is that for perceiving and thinking a precondition is a cognitive map which can suggest an orientation of the current situation in relation to the environment (Neisser 1976; Piaget 1985; Carroll 1993). In similar vein in management literature Daft and Weick (1984) proposed that organizations faced troubles in understanding the complex environment in which they were to take actions, why a map of the situation enabled organizations to model uncertainty and complexity, from which organizational stakeholders then could act and decide on directions for future work and thereby contribute to balancing organizations in reaching flexibility and efficiency. Fleming and Sorenson (2004) explains how using science as a map can guide you in technological search emphasizing the setting of this research. While the research on interruption advocates for a reassessment to take place - which can be effectuated in many ways, cognitive variety calls for a structured approach to this reassessment guided by cognitive maps visioning the situation when taken the environment into consideration. Eisenhardt, Furr et.al (2010) advocate that earlier literature focus on cognitive variety creating value due to contradictions (Brown and Eisenhardt 1997; Smith and Tushman 2005) will be replaced by future management literature which will emphasize “cognitive variety that enables flexible *recombination of individually efficient mental templates.*”(p.1269). In line with these arguments this research shows that for transforming scientific inventions into greater patent scope cognitive variety will be part of the process. A lead scientist from the firm having been part of a process that led to exceeding patents explained the process the following way: *“The process is normally this way, I put up some ideas... and then the IP person considers how it can be protected and the value. And after that we become sparring partners. I use many hours in testing ways to circumvent our patents, because we would like to have very strong*

*patents.*” Another scientist explained the cognitive mapping in the following way: *”I know the chemistry, they know the IP, and together we figure out how to protect the innovation. They (IP experts) look at the innovation and tries to structure it in 'boxes', and then they say 'maybe we can get better protection if..’ “*

In this research our findings suggest cognitive variety as a method to obtaining convergence in mental templates, one presented by the scientists in which the scientific opportunities and scientific landscape surrounding the invention is describes, whereas the patent experts presents a cognitive map for an applied technology in terms of the patent landscape. In formal terms, this finding suggests the following relationship:

Hyp 3; Patented inventions will be more likely to exceed the expected technological scope if patent experts mobilize *‘cognitive variety’* during the transformation phase from scientific invention to patented invention.

## **Abstraction**

Abstraction is the ability to generalize and conceptualize thinking. Examples of abstraction in management literature are still limited. However, Eisenhardt, Furr et.al (2010) refer to one in which managers of a Finnish venture realizes that their failure in hiring of locals in US could not be done following the heuristics of the firm, hiring online, why they changed the method of hiring to be non-restricted to only online applicants, but still hiring locals. In this research the exceeding patents scopes are correlated to the way that patent experts mobilize abstraction. One of the ways in which patent experts create value by abstraction were identified when patent experts identified higher levels of chemical structures, biomarkers, sulfurs, etc. resulting in the patented invention exceeding scientific scope, as described by a patent expert in a comment to an assessment of the patent scope comments: *“Patent covers a group where the invention only is a part of.”* Or another example originating from the university case where the scientist describes the invention as the result from the abstraction

process as: *“The patent agent made an invention on top of our invention”*, while one of the patent experts taking part in the process when the patent was drafted explained the patent scope in the following way: *“Because the way the patent was constructed with a graph showing the different estimates of thresholds of specificity and sensitivity. This increased technological scope.”* However, also abstraction which led to solution having no positive effect on efficiency and flexibility in terms of patent scope was proposed. One scientist explained how useless abstraction could occur if expertise and understanding for the area was limited: *“Algorithms were inserted in the invention, however, it did not give any additional value ...”* Another way of creating value from abstraction is done by the patent experts as they foresee which situations that will occur in the future, and ensure that they are taken care of with the current invention. The lead scientist from the university describes the abstraction conducted by the patent expert in the following way: *“If you are good at chemistry and biology, then you will be capable in understanding our invention. Then when you on top of this knowledge have an enormous knowledge of intellectual property rights, then you can make a ‘world map’ for us and say ‘listen friends we should go this way, haven’t you done that? No? Then go home and do so. Because if we get that as well, then we will be much stronger if we face this challenge in the future.”*

Exceeding patent scope calls for patent experts to perform mobilizing actions, applying abstraction to the process. Patent experts are uniquely qualified to carry out these actions as they have a deep understanding of both the scientific invention and the opportunities offered by the patent system and patent landscape, which they can navigate to identify the exceeding potential of the scientific invention. In formal terms, these findings suggest the following hypothesized relationship:

Hyp 4; Patented inventions will be more likely to exceed the expected technological scope if *patent experts perform 'abstraction' during the transformation phase from scientific invention to patented invention.*

The expertise of a patent expert was also mentioned extensively during the interviews, this reflects much literature which finds expertise having a positive effect on performance.

However, in the interviews expertise was identified as a pre-condition for mobilizing both abstraction and cognitive variety which could benefit the transformation process. In addition organizational structure, ensuring patent experts as part of the innovation process occasionally, showed to be a precondition in ensuring interruption, as scientists could be too focused in their scientific work, or might not want to include patent experts as the work with patent experts were time consuming.

## **TESTING THE HYPOTHESES**

Extensive testing of the hypothesis was done utilizing the method presented by Abell (2009).

After coding each narrative to pertain to either of the constructs, the results from the assessment from the jury was analyzed. I analyzed the hypothesized relationships by analyzing the results from the likelihood ratios, hereunder how differences among experts, internal vs. external, types of quote and counterfactuals showed to impact the results.

Interruption received significant higher assessment from internal process stakeholders as opposed to external. Abstraction and cognitive variety did not show significant differences between internal and external evaluations of evidence.

## **DISCUSSION AND CONCLUSIONS**

In general, the findings presented here extend both the psychology based management literature and the innovation literature in that a model is proposed of a transformation that

creates patents that exceed the scope of the original scientific invention. Patents that exceed the scope of the scientific invention are patents in which new insights leading to greater technological scope are generated ex post the creation of the scientific invention and ex ante the awarding of the patent. I show how this surplus depends on processes related to abstraction and cognitive variety mobilized by patent experts who have both an in-depth understanding of the scientific discovery, due to their educational background in the life sciences, and capabilities in the legal framework of patenting. This gives them a cognitively different approach to scientific invention than that of the scientists (inventors), allowing them to mobilize actions in which additional opportunities for exploitation are identified and hence to extend the invention into dimensions not proposed by the scientist. The reason for extending the technological scope of the scientific invention is to secure the freedom to operate in order to conduct further work on the invention as well as to secure patent protection that is adequate to appropriate returns if a future product launch based on the scientific invention is made. Furthermore, I also find that the technological scope “fought” for in the examination process of individual patents, a time-consuming process that takes place over several years and is orchestrated by the patent expert, is influenced by knowledge of how exploitation of the given invention is to take place. The direction of exploitation must therefore be determined early in the process, immediately after the scientific discovery has been made, in order to guide the IP owner through the examination process. While I identify such iterative processes between business, IP, and science as part of the transformation process in the firm under study, I also find them largely absent in the inventions created at the university. More specifically, the findings reveal previously unreported aspects of the transformation of academic science into patents, particularly how university scientists take a fragmented approach to the patenting process, while firm scientists can reap the benefits of close interaction with patenting experts, who may potentially assume responsibility for

searching for new directions of development if challenges of exploitation arise with regard to the scientific invention.

Together these findings recast the relationship between science and patents as a process in which the transformation treatment the scientific invention receives affects the patent scope of the patented invention. To unleash the greatest possible patent scope, the innovation process must incorporate certain developments. First, an interruption needs to take place. If no organizational structures of interruption are in place, instances of “lost” patent scope will likely occur. Second, iterations between scientists and patent experts are needed in order to unlock the potential for greater patent scope. These include actions mobilizing the effects of abstraction and cognitive variety, which have been identified as central to generating exceeding patent scope. These findings highlight how the micro-foundations of interruption, cognitive variety, and abstraction, which have previously been identified as important measures in balancing flexibility and efficiency (Eisenhardt, Furr et al. 2010), also play a role in boosting the value of science in the patent scope through the transformation process.

In this paper I also contributed to method development by offering a first attempt at applying the case study method introduced by Abell (2009). Abell (2009) proposes that narratives add paths of causal links to a chronology of events and actions. This perspective enabled me to study the links identified in the cases as Bayesian inferences generating Bayesian narratives, and examine them through a lens that dictates that the causal paths in a narrative have a Boolean structure. This makes it possible to conduct an analysis of the cases in which narratives are presented and assessed by a jury as evidence of causal links in order to estimate the posterior odds, conditional on the evidence, by explicitly investigating the causal inferences in each of the cases. Furthermore, applying this method offered a distinct opportunity to investigate the narratives through the lenses of both internal and external



stakeholders in the innovation processes. This highlighted where I should be cautious in interpreting the linkage proposed, but also provided me with estimates of posterior odds, the use of which has previously been neglected as an approach to case studies, even though it provides an opportunity for case study practitioners to obtain likelihood ratios of proposed hypotheses when large N studies are not possible.

The view I present here of the transformation of science into patented inventions has implications for theories of innovation. The findings confirm prior studies suggesting that science is used as an input to technologies (Tijssen 2002; Ahuja and Katila 2004), support the findings presented by Gittelman and Kogut (2003) and Murray (2002), and provide further explanations for the outcomes of their studies. I also extend the organizational literature, which has highlighted the importance of an exploitative and explorative organizational nature in creating high performing firms (March 1991), by identifying and testing the micro-foundations presented by Eisenhardt, Furr et al. (2010) and how they influence the complex process of transforming science into patented inventions. In essence, this paper proposes a specific relationship between science and patents in terms of patent scope.

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## TABLES AND FIGURES

**Table 1: Description of cases: The scientific discovery and after the transformation – the patented invention**

Scientific invention	Patented invention	Case	#Of Interviews
It is possible to predict whether it is blood from a healthy or a sick person with TIMP-1	Detection of cancer with TIMP-1 (#1)	University	Total: 8 (5,3) <sup>1</sup>
Level of * in a person changes over time dependent on whether the person is sick from cancer or in a well period at the time	Patent on monitoring via TIMP-1 (#2)	University	Total: 8 (5,3)
TIMP-1 and PAI-1 inhibit programmed cell death, two usages: predicative biomarker or as part of treatment	Patent covering TIMP-1 and PAI-1 as predicative biomarker and treatment (#3)	University	Total: 8 (5,3)
Enhanced predicative analysis	Patent covering prognostic stratification of colorectal cancer (#4)	University	Total: 8 (5,3)
TIMP-1 as a prediction is shown to be different in populations	TIMP-1 and TOP2 (#5)	University	Total: 8 (5,3)
Substance X <sub>1</sub> against disease Z <sub>1</sub>	Patent focusing on substance X <sub>1</sub> (#6)	Firm	Total:14 (8,6)
Substance X <sub>1</sub> against disease Z <sub>1</sub> & phase 2 results	Patent focusing on substance X <sub>1</sub> with “transporter” (#7)	Firm	Total:14 (8,6)
Interview & brainstorming outcome (Invention 1)	Patent filing on new product strategy, patent 1 (#8)	Firm	Total:15 (8,7)
Interview & brainstorming outcome (Invention 2)	Patent filing on new product strategy, patent 2 (#9)	Firm	Total:15 (8,7)
Interview & brainstorming outcome (Invention 3)	Patent filing on new product strategy, patent 3 (#10)	Firm	Total:15 (8,7)
Invention X for disease Z	Patent focusing on X <sub>1</sub> as mono therapy against disease Z (#11)	Firm	Total:15 (10,5)
Invention on X for disease Z	Divisional patent application, Patent focusing on X <sub>1</sub> as add on against disease Z (#12)	Firm	Total:15 (10,5)

<sup>1</sup> In the parenthesis, the first number shows the number of interviews held with scientists and other stakeholders in the drug discovery process; the number after the comma shows the number of interviews with patent experts.

## Figures: Chronology of Events Transformation of Science into Patents

Figure 1: Case 1 to 5: Chronology of events at the University

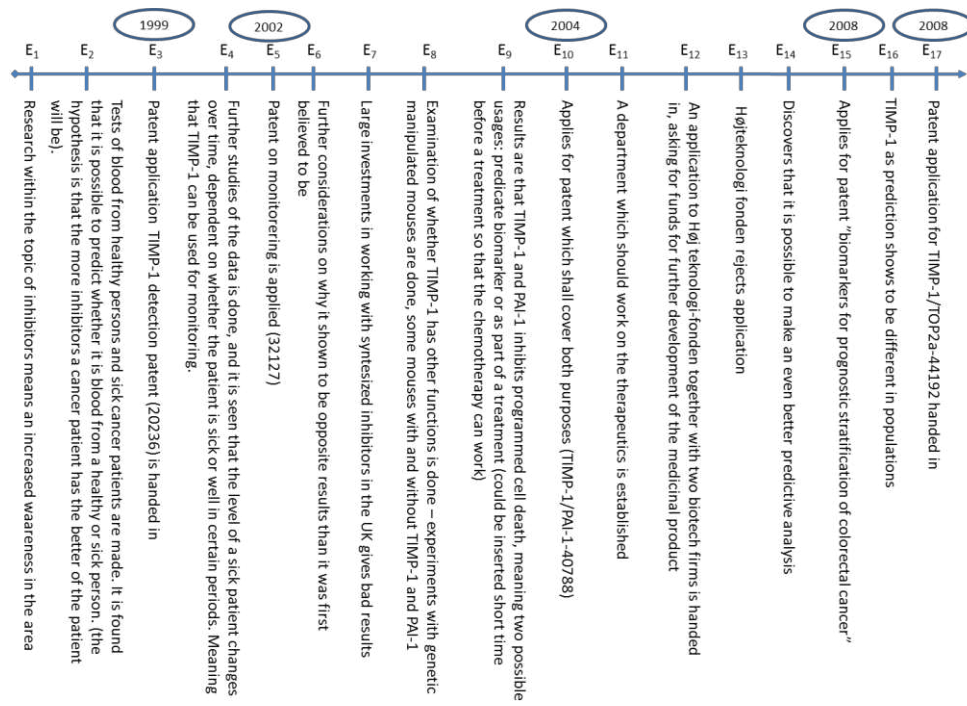
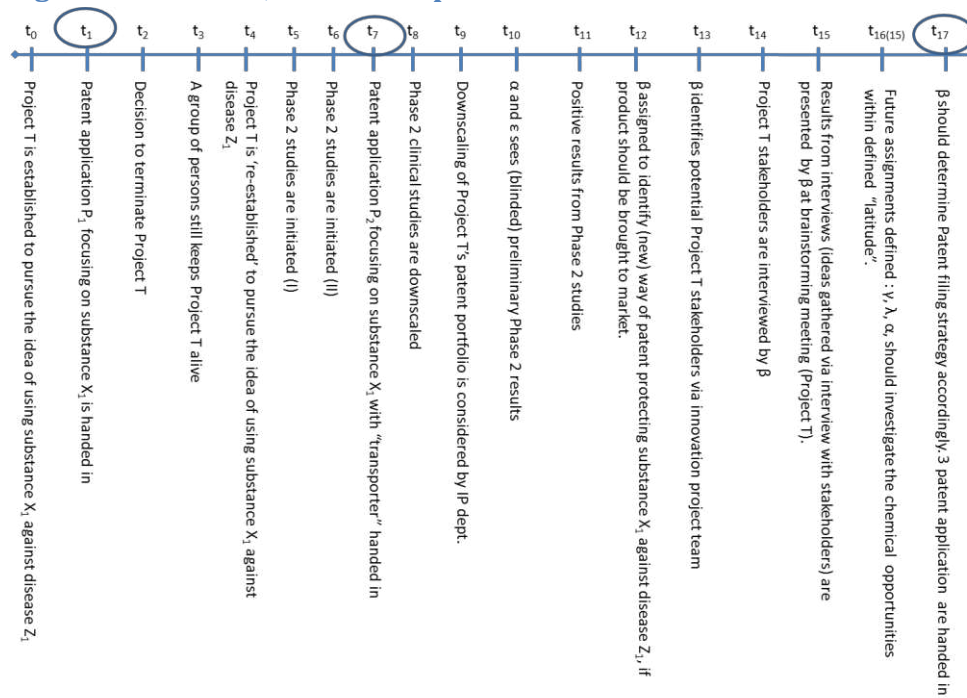
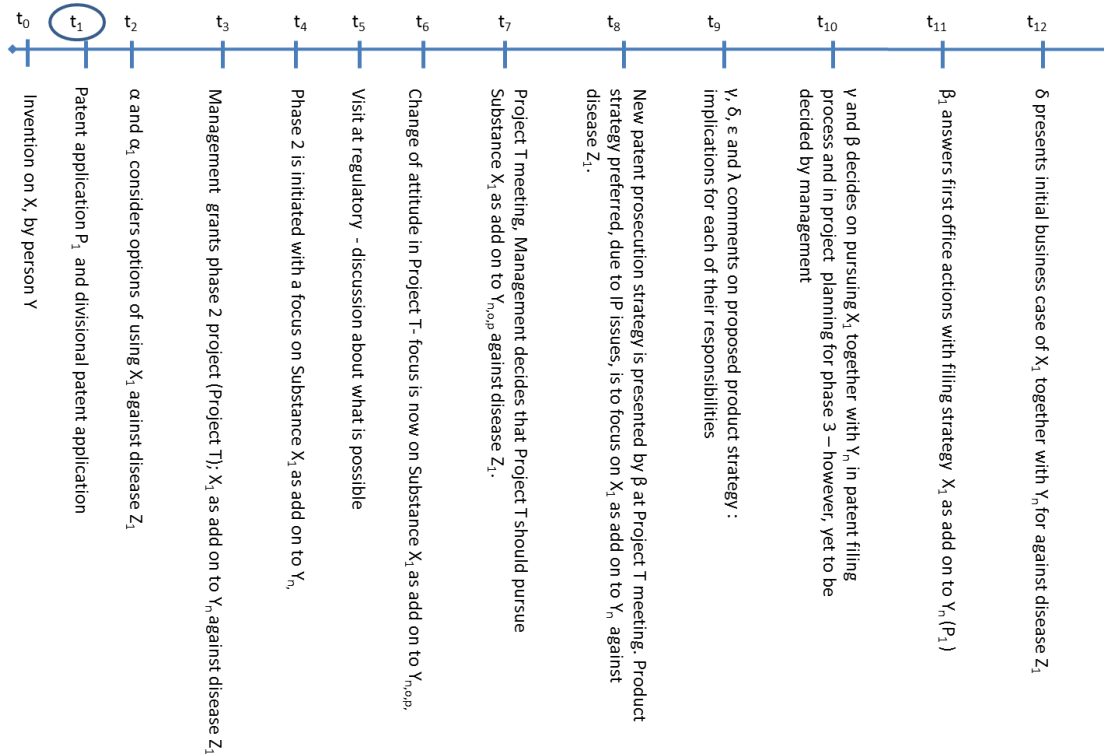


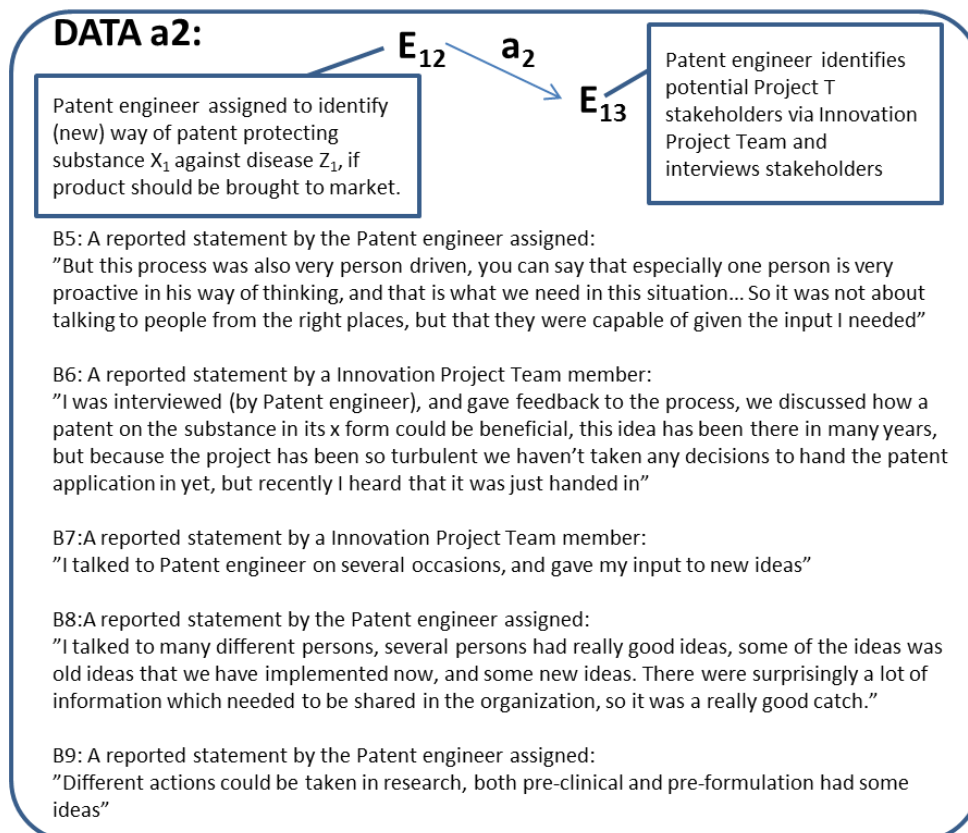
Figure 2: Case 6-10, Innovation process at firm



**Figure 3, Case 11 & 12: Innovation process at firm**



**Figure 4, Example of quotes as evidence**



**Table 2: Overview, likelihood assessment from jury members: differences and coherences**

Quote	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12	b13	b14	b15	b16	b17	b18	b19	b20	b21	b22	b23
Hypothesized relationship	a1	a1	a1	a1	a2	a2	a2	a2	a2	a3	a3	a3	a3	a4	a4	a4	a5	a5	a6	a6	a6	a6	a6
Expert 1	3	9	3	1	2	1	1	1	1	8	1	1	7	10	4	4	10	10	10	5	1	2	1
Expert 2	3	4	8	6	6	1	1	5	1	10	1	1	10	4	1	1	4	4	4	4	4	5	1
Expert 3	10	8	10	8	10	7	7	10	10	10	6	8	10	10	8	8	6	6	10	10	1	10	10
Expert 4	5	8	10	7	8	2	5	10	1	8	8	9	1	10	1	10	5	5	5	9	1	9	7
total	21	29	31	22	26	11	14	26	13	36	16	19	28	34	14	23	25	25	29	28	7	26	19
mean	5,3	7,25	7,75	5,5	6,5	2,75	3,5	6,5	3,25	9	4	4,75	7	8,5	3,5	5,75	6,25	6,25	7,25	7	1,75	6,5	4,75
st.dev	3,3	2,2	3,3	3,1	3,4	2,9	3,0	4,4	4,5	1,2	3,6	4,3	4,2	3,0	3,3	4,0	2,6	2,6	3,2	2,9	1,5	3,7	4,5

**Table 3: Experts' overall and internal vs. external experts' assessments**

		Number of times the assessment '1' used	Number of times the assessment '10' used	Total (b1+b2+...+b23)	Average likelihood ratios
External	Expert 1:	9	4	96	4,2
	Expert 2:	8	2	89	3,9
Internal	Expert 3:	1	12	193	8,4
	Expert 4:	4	4	144	6,3



**Table 4: Patent Applications, below, expected or exceeding technological scope**

Patent ed inventi on	Performan- ce techno- logical scope	Case	ASSESSMENT 1		ASSESSMENT 2	
			Catego rical assess ment	Comments	Catego rical assess ment	Comments
(#1)	Exceeding	University	3  (1)	3: because the way the patent was constructed with a graph showing the different estimates of thresholds of specificity and sensitivity. This increased technological scope. 1 because we simply forgot to write "saliva" in the patent app. Which turned out to be important for (patent #2) this was only identified later when applying for (#2)	3	The patent agent made an invention on top of our invention
(#2)	Expected	University	2	The patent later turned out to be in trouble from prior art due to prior academic publication from the inventor team.	2	Nothing added
(#3)	Exceeding /Expected	University	2	The patent was not well-made from the beginning, there were problems with fist five claims	3	Na
(#4)	Below/ Expected	University	2	Na	1	Algorithms were inserted in the invention, however, it did not give any additional value, and they simply forgot areas.
(#5)	Below/ Expected	University	2	Na	1	The patent agents could have been more active in understanding the invention
(#6)	Exceeding	Firm	3	Patent covers a group where the invention is only a part of.		Na
(#7)	Exceeding	Firm	3	The transformer of the invention was the core of, however the technological scope also covers intermediary and the manufacturing process		Na
(#8)	Expected	Firm		The method of precipitate		Na
(#9)	Expected	Firm	2	The method of precipitate, Utility patent, very narrow, patent expert together with scientists sat down and identified the invention to be protected in the data received from screening.		Na
(#10)	Expected	Firm	2	Late in invention process so not much room to go for. Patent application based on extra clinical studies		Na
(#11)	Expected	Firm	2	This patent was very closely drafted in accordance to the invention done		Na
(#12)	Exceeding	Firm	3	In this patent application the group of substances the invention Z to was eventually included in the application.		Na

## APPENDIX 1: INTERVIEW GUIDE

TABLE 1	INTERVIEW GUIDELINE
a. Chronology of events	Do you agree with the proposed timeline of events? Did anything significant happen between E <sub>0</sub> and E <sub>1</sub> ? (focus on the events on the timeline in which the respondent has been an active participant)
b. Gathering narratives	Focus: find motives/reasons for performing different actions/events. Interviewee can either be an active participant in the event or an observer of the event. What was your motive for doing a <sub>1</sub> ? / What was the reasoning behind doing a <sub>1</sub> ? (only ask observers of the action if there is enough time)
c. Gathering Counterfactuals narratives	In regard to the counterfactual questions, the following table presents the overall framework for asking questions to identify whether an event/action is sufficient and/or necessary. Did you do a <sub>2</sub> because of a <sub>1</sub> ? If a <sub>1</sub> had not happened would you have done a <sub>2</sub> ? Remember - in Context (C <sub>1</sub> )
d. Capabilities	Try to identify what capabilities are needed to give valuable results during the iteration in the innovation project group, and what it is that an IP person who is employed by the firm and who is part of the R&D project group can “apply”. (the following questions need not be asked if the interviewee answers the above question) Why were these persons able to do a <sub>1</sub> ? Describe the capabilities utilized during the innovation process (focus on each of the different events and the evidence discussed above in questions A to F)? Did E <sub>2</sub> occur because a certain set of capabilities were utilized in E <sub>1</sub> ? Which? Would E <sub>2</sub> have happened without certain capabilities in E <sub>1</sub> ? Which? Could these capabilities have been used in E <sub>1</sub> without E <sub>2</sub> happening afterwards? If these capabilities had not been utilized in E <sub>1</sub> would different capabilities be needed in E <sub>2</sub> as well?
e. Successfulness	Do you think the process has been successful? Why? (Asked to identify the context of the case.)

## APPENDIX 2: PATENT ASSESSMENT – DEPENDENT VARIABLE

### Evaluation of patent X

*Invention: (short description)*

*Patent: Patent application*

Please fill out the table below by circling your answer. Decide first, whether it is a basic or an applied invention and second, the degree to which the technological scope is below the level expected, at the expected level, or exceeds the level expected, keeping the invention in mind:

Is the scientific invention on which the patent is based basic or applied?	Applied Science	1A	2A	3A
	Basic Science	1B	2B	3B
		Patent application covering <b>(only)</b> parts of scientific invention	Patent application covering the scientific invention	Patent application adding new aspects to scientific invention
		Below expected scope	Expected scope	Exceeding scope
<b>Technological scope of patent</b>				

Please explain your reason for evaluating the given patent in the “scope” category :

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