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Science and IP as Complementarities in Technological Innovation

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Abstract

This paper examines organizational capabilities established by small high-tech firms to bridge substantially different competencies of critical importance for their commercial performance. Focusing on the two sets of competencies referring to corporate research and generation Intellectual Property (IP) we study the organizational forms connecting them in terms of their effects on patent value. Investment in internal IP counsel is found to drive value more strongly than does engagement of external IP counsel. Patent value also is found to be enhanced when firms take the level of interaction between R&D and IP to a high level of intensity. The ability to maintain and exploit high interaction intensity represents a firm-specific organizational capability. We test and confirm that when combined with high quality of firm-internal research these organizational capabilities give rise to complementarities positively affecting patent value.

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Abstract

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INTRODUCTION

During the last decade, patent filings have increased yearly by 1 or 2 digit percentages, providing a strong indicator of firm's increasing focus on improving performance by IPR[1] protection. At the same time, the impact of IPR protection on firm performance has become a popular and multidisciplinary research subject, generating significant research body of empirical, theoretical and anecdotal knowledge, accumulated in law, economics, patent innovation and management literatures(Lynskey, 2006; Rivette & Kline, 2000). The core issue in this literature is the question as to *how* firms generate IPR protection which enhances their performance (Teece, 1986). The common implicit assumption holds that inventions become commercially valuable simply by patenting them as they appear from research departments. However, IP departments often play a pro-active role in shaping innovations instead of merely being passive recipients of research results (Granstrand, 1999), taking them beyond the tasks of merely writing and scoping the patent correctly. The present paper examines if IP counsel[2] in science-based firm plays such a pro-active role and whether it offers a distinct contribution to the value of patents.

Prior research suggests that organizational performance is based on the application of heterogeneous complementary elements, which reinforce each other in such a way that applying more of one element brings additional value to doing more of the other element (Milgrom & Roberts, 1990, 1995). However, even though a large number of empirical studies on complementarities have been conducted, especially in regards to innovation studies (see Ennen & Richter (2010) for a recent overview) complementarities between IP and in-house research upon innovation remain unexplored. In this paper we examine three dimensions of the relationship between research and IP. First we focus on differences between internal or/and external IP counsel effects regarding effects on patent value. Second, we examine the intensity of the interactions between IP counsel and research, again in terms of its effects patent value. Thirdly, we examine if strong corporate scientific quality and IP-related organizational capabilities are complements, i.e. whether the effects on innovation of combining high quality scientist with IP counsels add more value above the addition of their separate contributions.

[1] IPR= Intellectual Property Rights (here also used interchangeably as IP).Even though a wide range of IP rights are available (Patents, Design rights, Copyrights, Trademarks etc.) this study is focused on patents and how patent agents interact with R&D during product development.
[2] IP counsel is synonymous with patent attorneys, patent agents and patent lawyers.

We test our ideas in an empirical study using IP organizational and patent data in a sample of companies from the biotech industry. Biotech firm's profitability depends highly on their ability to develop new drug candidates that are eventually commercially valuable; IP expertise is therefore an unavoidable and very important input to their business. Our main findings are 1) that Internal IP counsel is the critical factor in building patent value, as opposed to external IP counsels. 2) A significant relationship is found between intensity of interaction between IP expertise and scientists and patent value output. 3) A complementarity effect is confirmed between science and IP expertise; high performing scientist produce valuable patents if closely interacting with IP counsels, whereas the value of the patent outcome decreases if treated separately.

The remainder of the paper is organized as follows: In the second section we consider how the choice of organization of IP is made within the larger system of innovation processes in firms. We then discuss the IP expertise and R&D interaction decision itself and motivate the definition of R&D and IP intensity used in our study, in this section we also briefly introduce what characterizes IP counsels. This is followed by our hypotheses regarding the complementarities between IP expertise and science and how this relates to patent value. Our empirical analysis follows, and we conclude with a discussion of implications, limitations, and potential extensions of the research.

ORGANIZING THE INTERFACE BETWEEN SCIENCE AND IP

During the development and management of the IP organization important decisions must be made: Do we wish to hire an internal versus an external IP counsel? What kind of engagement would we prefer the IP counsel to have in the R&D project? Thus, how often do we wish the IP counsel to be engaged in the project? What should the objectives of the IP counsel be? And what background and kind of IP counsel do we wish to engage in the R&D project? These questions are interrelated and the answers might change over time but will always have an impact on the degree to which an IP counsel becomes involved in and influences the outcome of the R&D project.

Previous research has taken different approaches to IP in organizations. One part of the literature is based on cases of single IP organizations. Examples are Toshiba and Hitachi (Granstrand, 1999), Eastman Chemical Company (Gwinnell, 1997), Dow Chemical (Petrash, 1997), Avery Dennison (Germeraad, 1997), Neste (Laento, 1997), Xerox (Daniele, 1997a; Daniele, 1997b), the

cases have shown differences in the way firms organize the involvement of IP counsel in R&D. Gwinnel and Manfroy (1997) explain how a spin-off from Kodak Eastman establishes its IP organization, which meets with the R&D personnel at several occasions, first to establish and identify potential IP, thereafter to initiate filing process, as well as having IP counsels involved at firm "steering meetings" to ensure a focus on IP. In the case study presented on Avery Dennison (Germeraad, 1997) the focus of the IP department changed over the years. At first the R&D division managed their IP portfolios, including making decisions on patent scopes, filing and patent-administration. Later on an IP organization was established including 3 IP teams covering each of three technological areas. The reasoning behind this organizational change was to get the IP staff closer to the ongoing R&D projects, with specialized IP counsels. This detailed empirical literature documents large differences regarding the level of interaction, organizational relationship between IP and R&D, ascribed obligations to each department, and deliberate reasoning behind organizational structure.

While the qualitative, case-based literature has presented insights into individual IP organizations, recent quantitative studies have approached the complex system of IP organization decisions in two ways. Reitzig and Puranam (2009) base their study on the Resource Based View exploring the relationship between IP capabilities and patent value. In a quantitative study of 30 R&D intensive firms in 8 industries they show that IP-specific appropriation capabilities are manifest and that their value lies in the way they are organized across organizational functions, resulting in an inverse u-shaped effect of functional specialization upon patent value. The independent variable, functional specialization, used in this study is calculated from a matrix referring to the organizational specialization of those involved in the IP process with three main determinants IP generation, IP protection or IP exploitation. Somaya, Williamson & Zhang (2007) show that having internal IP counsel employed has a positive effect on the number of patents in the given firm. So far no quantitative studies have considered IP organization in terms of the intensity of the relationship between IP expertise and research and its effects on developing valuable innovations.

In the analysis presented below, we remedy this situation, by exploring the consequences of IP organizations. In particular we examine the nature of the relationship between high performing scientist and highly intense work with IP, and how this effects the value of the resulting patents. We also examine the implications of the internal and external IP counsels' characteristics, as

well as the intensity of their activities (i.e the degree to which IP counsels are work together with the firms R&D departments).

CHARACTERISTICS OF IP COUNSELS AND THEIR ROLE IN TECHNOLOGICAL INNOVATION

A first step in understanding the role of IP counsel in technological innovation is to look at their background, and thereby the capabilities and mindset they complement scientists, similarly to the profiling made of patent inventors in e.g.(Giuri et al., 2007). To our knowledge no large scale studies, have analyzed the characteristics of IP consultants in a form that allow them to be linked to patent performance. For this purpose, a short characterization of the IP counsels is needed: In this research 122 IP counsels were identified working for the sampled firms, 52% held a Scientific PhD (examples being Biochemistry, Chemistry, Molecular Biology, Human Biology) whereas "only" 33% of the external IP staff held an PhD and 53% a Masters degree. In addition, 65% of the internal and 86% of the external IP counsels had passed an European Patent Attorney (EPA) examination[3], which requires a prior scientific degree as well as practical experience with IP work. The qualification is very demanding and in 2009 only 37% of the candidates passed the EPA examination (keeping in mind that many of these all ready has obtained a scientific PhD degree). IP consultants, in other words, are well educated in their field of expertise and often have an additional relevant scientific background enabling in-depth understanding of science and technology issues.

The role played by IP counsel in a firm depends on the nature of the assignments performed by the IP counsels, these can be of very different nature. Two different assignments performed by IP counsels have been identified; IP counsels working with the focus on 'protection' or/and a focus on 'innovation'. The assignment relating to 'protection' focuses on securing IP protection for new products. The IP counsel discusses the invention with the scientist, the IP counsel maps the surrounding patent environment, ensures that the new product has 'freedom to operate' (can enter the market without infringing other IP owners) and the IP counsel hands in patent application(s) in the scope of the invention, in order to prevent other firms from utilizing the invention, ensuring commercialization of the innovation.

[3] Regarding the EPA education read more at http://www.epo.org/patents/learning/qualifying-examination.html.

When the IP counsel has its assignment focused on 'innovation' related assignments, the IP counsel searches for knowledge input to the discovery/invention process. The available knowledge in patents is different from that of scientific journals, and IP experience is needed to understand and translate the knowledge gathered in patents into the scientific 'language' of the scientists. Also patents often, give the first indications of the commercial potential of new discoveries. Most often firms await handing in scientific publications, until the patent related to the invention is made public as part of the patent filing process. An IP counsel's work can also include being a main stakeholder and initiative taker in an innovation project: for example if IP challenges arise, an example could be that the innovation project has been on the way for so many years that the supportive patent protection will run out prior product is ready to be launched on the market. The IP counsel would then be main driver in a process of searching for knowledge, both in R&D and IP in order to identify additional inventions which could be supportive of the protection running out.

CAPABILITIES, ORGANIZATIONAL FORM AND COMPLEMENTARITIES IN DEVELOPING VALUABLE INNOVATIONS

So far few attempts have been made to theoretically and empirically link a firm's usages of IP, during R&D, with innovation outcomes. To understand the contribution of IP we must consider its role in developing and scoping a commercial innovation. In the innovation literature the classical view has emphasized a linear sequence invention → innovation → diffusion (Schumpeter, 1934). Recent literatures, particularly since Kline (1986) and Quinn (1985) have emphasized non-linear, feedback rich, and iterative qualities of the innovation process (P Braunerhjelm, 2006). Quinn (1985) emphasizes that the innovation process is *"full of surprises"* implying that the innovation process is chaotic, whilst, still containing feedback loops. The close connection between a non-linear understanding of innovation and RBV has spurred research on forward and backward feedback loops in many different aspects of innovation, ranging from linkages between product development and production (Sanchez, 2009) to anticipation of user reactions (von Hippel, 1988). On this basis the innovation literature recognize a process that encompasses both the creation of new technical ideas and their appropriation into valuable products. Collaboration among different stakeholders during the development and appropriation process is recognized (eg. marketing, production, technical and sales departments) as contributing to the commercial success of new products. In spite of this common understanding

of the innovation as being a feedback-rich process, an important construct remains neglected; namely the interactions between innovation and IP.

Internal or/and External IP counsels engaged in firm's R&D process

Until now, it has only been suggested in the case study literature that IP counsels collaborating in R&D projects can add core capabilities different from those of scientists and other participants in the team. The literature on capabilities shows how different capabilities and resources when combined create firm value (Teece, 1997) and secure appropriation (Moran & Ghoshal, 1999; Reitzig & Puranam, 2009; Rivette & Kline, 2000). When choosing between internal and/or external IP counsels to be engaged in the R&D process of the firm, the potential value derived from using one or/and the other is assessed as being a specialization question. The answer to this focal issue ultimately concerns the degree to which specialization of IP counsels to a firm's R&D is beneficial in developing valuable patents. Our empirical investigation of this question focuses on whether having internal or/and external IP counsel capabilities engaged in R&D development affects innovation value. Previous studies provide a number of testable statements about specialization of resources in firms. Fox (1998) proposes, in his normative work in line with specialization theory, that there is a difference as to whether it is internal or external IP counsels handling the patenting process in firms. He emphasizes that the internal IP counsels have the benefit of knowing the firm's technologies and businesses and can thereby increase performance of the patents, whereas external IP counsel is used when the internal IP counsels capacity is constrained. Specialization has been widely recognized in literature; the main argument is that the potential value derived from specialized resources along with other resources in the firm is higher than that of these that are non specialized (Dierickx & Cool, 1989; Mowery, Oxley, & Silverman, 1996; Powell, Koput, & SmithDoerr, 1996; Teece, 1986). In our empirical investigation of the relationship between IP and innovation, the degree of specialization will be investigated by considering whether the IP counsel, engaged in a firm's R&D process, is either internal or external. The knowledge added from external IP counsels is regarded as less specialized than that deriving from internal, therefore we hypothesize:

HP1: A firm with internal IP counsels (as compared to external IP counsels) produces patents of higher value.

Organizational form and intensity of interaction between IP expertise and R&D process

Specialization of resources in firms is closely related to decisions on organizational form. It is widely recognized that organizational form has an effect on innovation outcome (Andriopoulos & Lewis, 2009; Eisenhardt & Schoonhoven, 1990; Katila & Ahuja, 2002; Puranam, Singh, & Zollo, 2006). Particular attention has been given to how successful commercialization is dependent on the coordination across various organizational units (Brown & Eisenhardt, 1995; Zahra & George, 2000). According to Brown & Eisenhardt (Brown & Eisenhardt, 1995, 1997; Eisenhardt & Martin, 1999) and Zahra & Nielsen (2002) firms need to cycle repeatedly through phases of exploration and exploitation in order to bring an innovation to market. The performance of the iterative process between R&D and IP therefore not only refers to the choice between external vs. internal counsel, it also concerns the question of the intensity of the interaction between IP and R&D (high, medium and low intensity). The organizational structure with high intensity supports repeated interactions between IP expertise and R&D compared to the low intensity organizational structure, where IP and R&D hardly interacts during development of new technological innovations. Therefore, we expect:

HP2: The value of patents from a firm increases with the intensity of interaction between scientists and IP expertise during R&D.

Strong scientific performance and IP related organizational capabilities as complementarities

The three first hypotheses have focused on the organizational form by which firms connect inventive processes with IP expertise. A high level of interaction between R&D and IP is possible only if the firm has put into place routines for reciprocal reporting, communication and coordination. Such firm-specific routines typically emerge though iterative learning and may be referred to as organizational capabilities (Grant, 1996; Zander & Kogut, 1995; Zollo & Winter, 2002). Organizational capabilities are context specific (Collis, 1994; Teece, Rumelt, Dosi, & Winter, 1994) so they should be empirically investigated in their specific context (Dyer & Nobeoka, 2000; Zander & Kogut, 1995). We do so by considering the ability to carry out and maintain high intensity of interaction between IP design and research as representing an organizational capability

Gittelman & Kogut (2003) showed that strong corporate science translates into valuable patents only when technological experience is made part of the inventive process, suggesting that firms must both create knowledge and act as an organizational mechanism to combine the capabilities of their scientists with the surrounding environment in order to produce valuable innovations. Stronger appreciation of the commercial and competitive selection pressures need not to come only from technologically experienced co-inventors, it also can emerge from organizational capabilities linking strong corporate scientists to IP expertise. Following the theory of complementary assets (Teece, 1986) we focus our fourth and final hypothesis on complementarities between the quality of the corporate research and organizational capabilities offering intensive interaction between R&D and IP:

HP3: Scientific performance and IP-related organizational capabilities build complementarities increasing patent value.

Taken together hypothesis 1 and 2 suggests differences between internal and/or external IP counsels effect on patent value, whereas hypothesis 3 expands this understanding, and suggests it is the individual IP counsel's intensity of interaction with R&D which effects patent value. Hypothesis 4 elaborates on the understanding of scientific performance and IP-related organizational capabilities, by identifying each of the complementarities position and each their added value in developing valuable patents.

DATA

An original data set of 66 Drug Discovery Firms (hereafter written DDF) that have been or still are active in Denmark is used in this analysis. These 66 DDF firms contain the population of DDF in Denmark during the time period of 1989 and 2004. The first Danish DDF was established in 1989, thereafter several firms were established during the 1990ies (32% of the sample) and a majority in the 2000s (67%). As patenting activity and patenting output such as number of patents obtained and number of forward citations obtained are closely linked to industry, a focus on one very specific industry is essential to investigate the role of IP counsels. Empirical work confirms a strong presence of patents in Biotech firms (Cohen, Nelson, Walsh 2000; Wolfson, Emerson, 2008) – therefore this industry has been chosen for this study. Besides being highly patent active, DDFs are also strongly science based firms, exemplified in the literature as firms from this industry have a strong relationship between patent citations and

scientific publications (Verbeek, Debackere, & Luwel, 2003). As a result interactions between IP expertise and scientists are expected to be especially pronounced in DDFs.

The data analyzed in this paper is compiled from 3 different sources, first from our own data collection, second, EPO/OECD patent citations database and, thirdly, from SCANBIT-database, a proprietary database belonging to the Research Center of the Biotech Business at Copenhagen Business school, that has been the basis for a number of peer reviewed publications (Valentin, Jensen, 2007; Valentin et al, 2007; Valentin et al, 2008).

The data collected for this paper contains each DDF's IP-activities, its IP organization strategy including the individual internal and external IP counsel's activities and engagement within R&D during the period from 1989 to 2005. Since all data on the firms IP organization strategies and characteristics of their IP counsels engaged in the interaction with scientists are manually collected both from patent databases, CV databases, company surveys and validated by firm representatives, using time series is crucial. First, all IP counsels, both externally and internally related to the DDF were identified in patent applications as well as via international CV databases. Information obtained was validated by both the firms' corporate IP and external IP agents. While validating the data, the same person was asked to identify the work obligations the given IP counsel had in relation to R&D work. The persons contacted in the survey were selected due to their seniority in the firm. In average the persons contacted had been employed in the firm for more than 6 years. The persons contacted to validate data were briefly interviewed about their knowledge of their IP organization prior the validation process, to ensure their knowledge of the firm was adequate, and to test whether they were able to provide detailed information of activities over the time period of the study. The second source of data was the OECD/EPO patent citation database covering all patent applications published by European Patent Office and World Intellectual Property Organization, under the Patent Co-operation Treaty (PCT), from their introduction in 1978 up until 2006[4] (Colin Webb and Hélène Dernis, 2005). This data has been used in other pear reviewed articles (de Rassenfosse & de la Potterie, 2009; Harhoff & Hoisl, 2007; Schneider, 2008).

[4] Note: Version 2 of the database is used.

The firm data used; firms economic strength (FIRM ECO) and number of employees (FIRM SIZE) as well as individual scientist's performance is drawn from the *SCANBIT*-database.

MEASURES

For an overview of measures see Appendix 1.

Dependent variable

Patent value (Pat_Value)

Using forward citation as a proxy for patent value is widely established (Bruno Cassiman & Zuniga, 2007; Harhoff, Narin, Scherer, & Vopel, 1999; Reitzig, 2004). Comparatively, Lanjouw and Schankerman (1999) identified forward citations as a stronger predictor of patent quality than claims, backward citations and patent family size. Nevertheless actual interpretation of forward citation has been subjected to intense discussions and different understandings have developed over the last decade; Schneider (2008) uses forward citations as a proxy for "importance" or "quality" of a patent. Trajtenberg (1990) has shown there is a link between forward citations and a patents social value, whilst Jaffe, Trajtenberg & Fogarty (2000) find forward citations are a measure of the economic and technological importance of the invention. As the analysis, in this paper, is focused on firms which are heavily dependent on patents, forward citations refers to the technological strength of the invention behind the patent, which is also closely related to the importance of the invention to a firm's value.

As observed in the literature on forward citations (Almeida & Phene, 2004; Henderson, Jaffe, & Trajtenberg, 1998; Owen-Smith & Powell, 2003; Schneider, 2008) the measure is influenced by both the technology field and time. A control for technology scope is inserted. Controlling for time we only use forward citation that has been received within the first 3 years, giving all patents included in the study the identical time periods (3years) in which to receive forward citations.

Independent variables

Internal IP Counsels, External IP Counsels, Internal and External IP Counsels *(INT_IP, EXT_IP & INT_EXT_IP)*

In this study, both the firm's engagement with internal and external IP counsels is investigated. Two dummy variables are created, whether and internal IP counsel (***INT_IP***) is engaged in the firm in a given year and whether an external IP counsel (***EXT_IP***) is engaged in a given year. The variable ***INT_EXT_IP*** is created as a dummy variable which equals 1 when the firm has engaged both internal and external IP counsels and 0 when either internal or external IP counsels are working with firms R&D department.

IP organization (*ORG****)***

In order to assess the effects of having an identified approach to firm's IP organization, detailed data on each firm's IP organization and activities during the active period of the firm is gathered. Each IP counsel's interaction with scientists during R&D is coded (variable *ORG*), the variable contains 4 categories:

ORG_0: When there is no IP counsel active during R&D

ORG_1: 'Low intensity', IP counsel is contacted when R&D feels it is necessary

ORG 2: 'Medium intensity', IP counsels are active at stage gate meetings, either monthly or quarterly

ORG 3: 'High intensity', IP counsel active in R&D project groups.

The four categories are thus expressions for very different ways of engaging IP in the innovation process. From interviews held with firm innovation stakeholders we know that IP counsels, who are actively participating in R&D project groups, have an impact on the innovation process from the very initial invention disclosure and then all the way through the development and research. An example (in the case of ORG_3) an IP counsel investigates the patent landscape of a chemical substance and reports back to the project group assigned to the develop the innovation, that certain chemical structures are already occupied by other patents and additional development attention must be taken in certain directions where the patent landscape seems un-occupied (such as other indications, certain doses etc.). It can also be that certain development studies must be conducted with the chemical substance in order to differentiate it from prior art. For this kind of

engagement in a firms R&D project, the IP counsel must have in-depth knowledge of firms business and technology, and this can only be obtained by working closely with R&D during the innovation process (variable ORG_3). This close relationship between IP expertise and R&D, where daily iterations are apparent, is not apparent in the firms where the IP organization only deals with R&D less frequently. The medium IP and R&D interaction (ORG_2) is characterized by a different interaction model; R&D presents recent scientific developments at monthly or quarterly stage gate meetings where an IP counsel will be present. The IP counsel suggests IP considerations and is in charge of identifying whether scientists have overseen any IP issues that should be investigated before proceeding with the innovation. The measure ORG_1 indenter an IP organization which is passive, where the IP counsel awaits scientists to identify an invention which is interesting to look at from a patent protection perspective. This might result in scientists working for a long time on certain research projects which are constrained commercially (due to challenging IP issues) or scientist working on issues that are all ready invented, however, only public in patent literature. In general when interaction between IP expertise and R&D is low (ORG_1) IP has limited opportunity to direct issues which could strengthen the technical innovation and increase options to profit from the innovation.

Scientist quality (*SCI_QUAL****)***

A general acknowledged way of measuring a scientist quality is by measuring their authorship by each inventor's number of publications (available through ISI web of knowledge) up until two years after patent has been applied. The reason for this time span (t+2) after the patent application is that scientific articles are submitted after patent priority date (there is a novelty demand to patents). If several inventors are included in the patent it is the sum of their authorship that is coded. The variable (*COUNT_SCI_QUAL*) is coded as a count variable. For the purpose of testing high quality scientist complementarity with organizational capability, the variable is changed into a dummy variable, where *SCI_QUAL* equals 1 if *SCI_QUAL* is greater than *SCI_QUAL*'s mean, and 0 if *SCI_QUAL* is greater below *SCI_QUAL*'s mean.

We control for firm size (FIRM SIZE), Firms economic strength (FIRM ECO), the technology scope of the patents (PAT_TECH_SCO), the patents scientific relation (SCI_COM) and the competitive environment of the invention (COMP_ENVI).

METHODS

In the empirical analysis below, we begin by estimating patent value as a function the variables featured in our hypothesis. Since the dependent variable; number of forward citations has a disproportionate number of zeros, resulting in an over-dispersion, it is accounted for when model is chosen, insignificant z-tests indicates in all presented models that negative binomial regression is better than a zero-inflated negative binomial regression model, the negative binomial regression model is therefore used throughout the tests.

In the first estimations, we estimate the role of internal and/or external IP counsel, using an interaction model. As no firms choose to have no IP counsels working with firm innovations baseline is chosen to be 1. Second, we estimate the effects of IP organization on patent value (measured as a categorical variable: low, medium and high intensity) testing hypothesis 2. A Wald test is applied in order to see the effects of firms having an IP organization which chose medium (ORG_2) versus high intensity (ORG_3). An additional test of hypothesis 2 is done changing the IP organization variable into a dummy variable, only testing for whether firm IP organization is engaged in the R&D project group or not, as feedback loops in this highly intense process between IP expertise and R&D is much more apparent than in the two less intense organizational settings (medium and low).

The third estimate is a complementarity consideration, modeling complementarities originates from Milgrom and Roberts (1990, 1995) theory of super modularity. In this paper we use the approach to test whether science and organizational capabilities are complementarities, following the test model used by Arora & Gambardella (1990) Bruno, Cassiman & Zugina (2007) and D'Agostino, Laursen & Santangelo (2010). Two dummy variables are generated; one for scientific quality (SCI_QUAL) and one for organizational capability (ORG_CAP). SCI_QUAL takes the value 1 if the scientific quality is greater scientific quality mean (3.04). ORG_CAP takes the value 1 if the company has reported that IP counsels are working with high intensity (ORG_3) in firms R&D. Hereafter 4 variables are created: A) *SCI_ORG_CAP* equals 1 if SCI_QUAL is 1 and ORG_CAP is 1. B) *ONLYSCI_QUAL* equals 1 if SCI_QUAL is 1*ORG_CAP* =0. C) *ONLYORG_CAP* equals 1 if SCI_QUAL=0*ORG_CAP*=1. D) *NOSCI_ORG_CAP* equals 1 if *SCI_QUAL* is 0 and *ORG_CAP* =0.

A negative binomial regression is utilized to perform the test. A spearman test is performed to test whether coefficients are positive and significant. Finally a complementarity test is performed to see whether the complementarity test holds true: *SCI_ORG_CAP>= ONLYSCI_QUAL + ONLY ORG_CAP*.

The variable for scientific quality (SCI_QUAL) is additionally tested in 4 other ways, a) only accounting for the authorship at the time of patent application, b) including the authorship at the time of patent application plus 1 year, c) including the authorship at the time of patent application plus 2 years and d) the total authorship for the inventors of the given patent. All four tests confirm the results presented in this paper.

RESULTS

Descriptive statistics

Since some patents were acquired at DDFs start-up these patent were left out of the analysis, resulting in 29 patents to be dropped, which means the sample is 482 observations. Furthermore, out of the 482 observation, 362 observations on the IP organization intensity (ORG_1, ORG_2, ORG_3 & ORG_CAP) at the time of invention (priority date of patent), which constitutes a total of 75% of all patents developed by the Danish Drug Discovery Industry applied in WO + EP during the time period of the analysis (1989 to 2005). Even though data on external and internal counsels have been collected at the same time as the organizational form data, the responses here were slightly higher INT_IP (n=393) and EXT_IP (n=398). The reason for this discrepancy is, when the respondent answering the survey they did not know what organizational position a prior IP counsel had worked under, however they knew that this IP counsel had been engaged in firm R&D activities, in these cases the ORG-variable was left out while information concerning their work as related IP counsel either internal or external was included in the data. Table 1 provides descriptive data for all variables.

--place Table 1 about here--

Several interesting features of our sample emerge from reading of this table. First, with respect to our dependent variable, forward citations on patents, resemble findings in prior studies using forward citations as dependent variable measure (e.g. Schneider (2008). In respect to our IP data, first the results in regards to having internal and/ or and external IP counsel engaged in working

with IP during the innovation process seems surprising. Looking detailed at the data, it is found that 37% of patents used in this analysis (140 out of 371) only an external IP counsels was engaged in firm doings, whereas a majority of cases (57%) are handled with both internal and external IP counsels, and only very few cases with only internal IP counsel (3%).

From the descriptive data we can also see that firms in our sample choose different approaches to handling IP organization (ORG_1, ORG_2 and ORG_3). Approx. 2/5 of the sample chooses to have high intensity interaction (ORG_3) with IP counsels engaged in the innovation process, and a little more than 2/5 choose to have low intensity (ORG_1), only 1/5 of the sample structures the IP organization as measured by ORG_2. No firms answered that they did not choose to cooperate with IP counsels (ORG_0). As the variable ORG_3 is defined by a very close relationship with the IP counsel, it is expected that firms having chosen this IP organization strategy also has internal IP counsels handling it. In order to investigate this we tabulate the relationship between the IP organization intensity and whether the firm has internal and external IP counsels engaged in R&D or only engage either internal or external IP counsels (see table 2).

--place Table 2 about here--

The table indicates that DDFs that chooses to have high IP organization intensity (ORG_3) does also utilize both internal and external IP counsels, whereas, there in only very few cases (2%) are examples where a firm chooses to employ both internal and external IP and then choose low intensity (ORG_1). The effects on patent value of having internal or/and external IP counsels will be estimated in the regressions below.

In table 3 and table 4 correlation matrix variables are presented. Few correlations are significant; none approaches a common 0.70 criterion for multicollinearity.

--place Table 3 & 4 about here--

Our first estimation results are shown in Table 5. The baseline is firms using both internal and external counsel. The results shows, changing from having an external IP counsel related to the firm versus not having an external IP counsel does not have any significant effects on patent value, neither positive nor negative. These findings support the prediction of Hypothesis 1 that firm internal IP counsel, as compared to external counsel, is the critical factor behind patent value.

--place Table 5 about here--

The support to hypothesis 1 is consistent with our specialization argument; however, when not seeing any effect of externals, it might be that what influences the impact on patent value is driven by a combination specialization and organizational structure, where specialization is driven by, not whether the IP counsel is hired internally or externally, but rather to which extent the IP counsel has the opportunity to impact the R&D process. Being highly specialized cannot have any impact if the counsel is not allowed in the iterative process it is to develop a new innovation. Applying the logic from previous research suggests that how successful firm's commercialization is dependent on coordination across various organizational units and that there is a need to cycle repeatedly through phases of exploration and exploitation in order to bring innovation to market. We estimate this in table 6, and the results show that there is support for the hypothesized effect from increase in IP during innovation process (HYP2). It is supported that both having medium intensity (ORG_2) and high intensity (ORG_3) interaction during the innovation process is more valuable than low intensity (ORG_1) in developing patents of higher value, again emphasizing IP expertise impact on innovation outcome.

--place Table 6 about here--

To test the relationship between ORG_2 to ORG_3 a Wald Test is applied. The result confirms that going from ORG_2 to ORG_3 has significant effect.

--place Table 7 about here--

These results support our contention that examining specialization of capabilities in the innovation process, should not only be a matter of whether an external versus internal IP counsel are engaged in the process, but a matter of how the individual IP counsel are actually utilizing their capabilities in the innovation process. Our results from the first analyses underline the need for revisiting the role of IP expertise in technological innovation. The results show that IP expertise in itself has impact on the value of the resulting patents. This research thereby expands the current understanding of IP expertise in the R&D process. Somaya (2007) showed that having internal IP counsels available in a firm had positive impact on number of patents, not focusing on the value creation process. Reitzig (2009) explained how IP-specific appropriation capabilities are manifest and that their value lies in the way they are organized across

organizational functions, we add to this understanding by showing that intensity of IP expertise in R&D has significant effect on value added to patents. Explaining that IP expertise is most beneficial when interacting closely (high intensity) with scientists. In this way we add to the discussion of determinants of patent value, where focus mainly has been on the effects of scientific capabilities on patent performance (Hall, Griliches, & Hausman, 1986; Hausman, Hall, & Griliches, 1984; Pakes & Griliches, 1980).

The last part of our analysis will therefore explore the relationship between scientific strength of the corporate researchers and organizational capabilities offering intensive interaction between R&D and IP in producing valuable patents.

For this purpose we modeled the test of complementarities following prior work by Arora & Gambardella (1990) Bruno, Cassiman & Zugina (2007) and D'Agostino, Laursen & Santangelo (2010). Descriptive data for the four variables created is presented in Table 8.

--place Table 8 about here--

In table 9 the results from the econometric analysis is presented. NOSCI_ORG_CAP was dropped due to multicollinearity. It is found that when high performing scientists interact in R&D project group with IP counsels (SCI_ORG_CAP), it is positively and significant correlated with patent value. The result that ONLYORG_CAP is positive and significant is not surprising, as this confirms our results from the first three analyses done in this paper, and in line with Gittelman & Kogut (2003) the results show that high scientific performance is negatively and significant correlated with patent value (ONLYSCI_QUAL).

--place Table 9 about here--

The null hypothesis of absence of complementarity test (SCI_ORG_CAP= ONLYSCI_QUAL+ ONLYORG_CAP) is rejected at a 0.01 significance level (see 'Complem.test' in table 9). This means that high performing scientists are better equipped to evaluate and exploit knowledge presented by IP counsels, resulting in IP expertise and science together being better at producing valuable patents, than IP treating the IP process alone or scientist treating the process alone. In short, IP expertise and science are complementarities, and the marginal return from having high

intensity interaction between high performing scientist and IP in firm is higher than the marginal returns from the two IP expertise and science separately (confirming hypothesis 3).

CONCLUSION

This research has attempted to bring new evidence on determinants of patent value. In particular, we have analyzed the connection between how firms IP organization is structured and the value of patents. Our *empirical* results can be summarized as follows *first* the descriptive data analysis shows there is a significant amount of firms choosing not to have internal IP counsels engaged in IP work, therefore studies of IP effects on patent value must include both considerations of internal and external IP counsels. *Second,* findings confirm that engagement of internal IP counsels did increase the value of the patents, whereas no significant were found from engaging external IP counsels. *Thirdly*, seeing ability to maintain and exploit high interaction intensity as representing a firm-specific organizational capability we test and confirm that when combined with high quality of firm-internal research these organizational capabilities give rise to complementarities positively affecting patent value.

By implication firms relying primarily on external IP counsel should give attention to obtaining high intensity in its interaction with firm-internal research. Furthermore, the paper suggests a broader perspective on determinants of patent quality/value, as depending not only on the quality of its R&D but also on the organizational capabilities connecting it to areas of complementary expertise.

In addition to the empirical findings presented above this research also makes a theoretical contribution to innovation theory. It is evident that IP expertise should be added to the "group" of complementary assets which adds value in the innovation process. Furthermore, the study suggests that utilizing a combination of specialization theory and organizational form theory in order to assess value creation in firms is beneficial, as they complement each other as theoretical lens, and adds to fully understand organizational determinants of firm performance.

Finally we investigated complementarities between organizational capabilities spanning IP and R&D and strong scientific performance. The results showed that synergies arise when both are present in the process of developing valuable patents.

At the same time, before drawing any firm conclusions, due to the small number of firms investigated, the results presented here can be further investigated in other countries to see whether the same IP organizational characteristics are present, and whether the results also holds true here. Furthermore, the results should be tested in other industries. Additionally this research calls for investigations into what IP capabilities are, and especially what capabilities that becomes apparent in the different IP organizations settings. A more detailed understanding of IP organizations and how IP counsels interact with scientists could give valuable insight into exactly what it is that is the determinant of creating valuable inventions.

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TABLES

TABLE 1: DESCRIPTIVE DATA

Variable	Obs	Mean	Std. Dev.	Min	Max
Pat_Value	482	.9024896	1.486192	0	14
ORG_1	362	38.95%	.4883125	0	1
ORG_2	362	19.61%	.3976196	0	1
ORG_3	362	41.43%	.4932938	0	1
INT_IP	393	62.84%	.483822	0	1
EXT_IP	398	95.47%	.2080613	0	1
INT_EX_IP	476	44.74%	.497757	0	1
COUNT_SCI_QUAL	353	3.042493	5.85729	0	34
PAT_TECH_SCO	482	4.267635	3.085232	1	20
FIRM SIZE	482	49.70747	52.47115	0	161
FIRM ECO	482	7.92e+08	1.36e+09	0	8.30e+09
COMP_ENVI	482	3.620332	4.296573	0	35
SCI_COM	482	2.620332	3.033945	0	20

TABLE 2: IP organization Intensity, Internal & External IP counsel availability

	IN_EX (1=Both internal & external IP counsel; O=Either internal or external IP counsel, but not both)		
	0	1	Total
ORG_1	134	7	141
ORG_2	32	39	71
ORG_3	0	150	150
Total	166	196	362

TABLE 3: CORRELATION MATRIX MODEL 1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pat_Value(1)	1.0000							
INT_IP(2)	0.1294	1.0000						
EXT_IP(3)	0.0366	-0.0034	1.0000					
PAT_TECH_SCO(4)	0.1775	0.1012	0.0452	1.0000				
FIRM SIZE(5)	0.0340	0.6189	0.1477	0.1177	1.0000			
FIRM ECO(6)	0.1069	0.4107	0.1299	0.1243	0.5666	1.0000		
COMP_ENVI(7)	0.1928	-0.0217	0.0302	0.1808	0.1701	0.1673	1.0000	
SCI_COM(8)	0.0683	-0.1860	0.1195	0.0446	-0.0872	0.0071	0.5741	1.0000
COUNT_SCI_Q (9)	-0.0630	0.2725	0.0883	0.0680	0.5205	0.1635	0.0902	-0.1122

TABLE 4: CORRELATION MATRIX IP ORGANIZATION INTENSITY

	ALL_CI~3	ORG_1	ORG_2	ORG_3
Pat_Value	1.0000			
ORG_1	-0.2304	1.0000		
ORG_2	-0.0013	-0.3945	1.0000	
ORG_3	0.2292	-0.6719	-0.4155	1.0000
PAT_TECH_SCO	0.1775	-0.0971	-0.0591	0.1437
FIRM SIZE	0.0340	-0.6168	0.0078	0.6043
FIRM ECO	0.1069	-0.3137	-0.0191	0.3260
COMP_ENVI	0.1928	-0.0278	-0.1527	0.1506
SCI_COM	0.0683	0.1153	-0.0832	-0.0471

TABLE 5: NEGATIVE BINOMIAL REGRESSION

HYPOTHESIS 1

	Model 1
Pat_Value	
NO INT	-0.820***
NO EXT	-0.503
NO INT AND EXT	-0.489
PAT_TECH_SCO	0.042*
FIRM SIZE	-0.008***
FIRM ECO	0.000
SCI_COM	-0.055
COMP_ENVI	0.093***
Constant	0.169
	[0.218]
lnalpha	
Constant	0.053
	[0.180]
Pseudo LL	-481.348
No of Obs	370
Wald-Chi2	44.48842***

* p<0.1, ** p<0.05, *** p<0.01

TABLE 6: NEGATIVE BINOMIAL REGRESSION HYPOTHESIS 2

	Model 1
Pat_Value	
ORG_ 2	**0.915*** **
ORG_ 3	**1.278*** **
PAT_TECH_SCO	**0.066*** **
FIRM SIZE	**-0.009*** **
FIRM ECO	**0.000** **
COMP_ENVI	**0.056*** **
SCI_COM	**-0.046**
Constant	**-0.925*** **
	[0.182]
lnalpha	
Constant	**-0.293**
	[0.220]
Pseudo LL	**-457.665**
No of Obs	**362**
Wald-Chi2	**60.0181*** **

*** p<0.1, ** p<0.05, *** p<0.01**

TABLE 7: Wald Test ORG_2 & ORG_3 HYPOTHESIS 2

	Chi2(2)	Prob> chi2
Model 1	34.47	0.0000
Model 2	36.56	0.0000

TABLE 8. DESCRIPTIVE DATA, SCIENCE & IP IMPACT, ONLY SCIENCE, ONLY IP, NO SCIENCE OR IP

	Mean	Std. Dev.	Freq.
SCI_ORG_CAP	1.1666667	1.6230216	78
ONLYSCI_QUAL	.5	.97808353	174
ONLYORG_CAP	1.4634146	1.8134962	82
NOSCI_ORG_CAP	.88601036	1.9678301	193

TABLE 9. NEGATIVE BINOMIAL REGRESSION

HYPOTHESIS 3

	Model 1
ALL_CITS_REC3	
SCI_ORG_CAP	0.751***
	[0.278]
ONLYSCI_QUAL	-0.611***
	[0.184]
ONLYORG_CAP	0.668***
	[0.221]
PAT_TECH_SCO	0.058***
	[0.022]
FIRM SIZE	-0.009***
	[0.002]
FIRM ECO	0.000
	[0.000]
COMP_ENVI	0.077***
	[0.020]
SCI_COM	-0.023
	[0.030]
Constant	-0.440***
	[0.169]
lnalpha	
Constant	0.239
	[0.154]
Pseudo LL	-642.635
No of Obs	527

Wald-Chi2	**70.74642*** **
Complem.test	**4.81**

*** p<0.1, ** p<0.05, *** p<0.01**

Appendix 1

LABEL	Content	Operationalization
Dependent variable		
Pat_Value	Patent value – a quality indicator of the patent in question.	Count variable, counting number of forward citations patent receives.
Independent Variable		
INT_IP	Internal IP counsel engaged in patent work;	Dummy variable; taking the value 1 when an internal IP counsel is engaged in firm a given year and 0 when no internal IP counsel is engaged in firm a given year
EXT_IP	Internal IP counsel engaged in patent work;	Dummy variable; taking the value 1 when an internal IP counsel is engaged in firm a given year and 0 when no internal IP counsel is engaged in firm a given year.
INT_EXT_IP	Internal and External IP counsel engaged in patent work;	Dummy variable; value=1 when the firm has engaged *both* internal and external IP counsels.
ORG	R&D and IP Organizational set-up.	Categorical Variable; ORG_1, ORG_2 and ORG_3 (see description below)
- ORG_1	Low intensity of interaction between R&D and IP	ORG equals 1 when IP Counsels are contacted when R&D feels it is necessary
- ORG_2	Medium intensity of interaction between R&D and IP	ORG equals 2 when IP Counsels are active in stage gate meetings, either monthly or quarterly
- ORG_3	High intensity of interaction between R&D and IP	ORG equals 2 when IP Counsels are active in R&D Project groups
ORG_CAP	Organizational capability;	Dummy variable; Taking value 1

		when organizational set-up is ORG_3 and taking the value 0 when ORG_1 & ORG_2.
COUNT_SCI_QUAL	Scientist's quality.	Count variable, counting the number of scientific authorships (by firm affiliated scientists) associated with one patent.
SCI_QUAL	Scientist's quality	A dummy variable, derived from COUNT_SCI_QUAL: Taking the value 1 if the scientific quality is greater scientific quality mean (3.04), 0= if the scientific quality is less than the scientific quality mean (3.04).
- SCI_ORG_CAP	High SCI_QUAL and High ORG_CAP Explaining the relationship between scientist's quality and organizational capability.	A dummy variable; Taking the value 1 when SCI_QUAL =1 & ORG_CAP=1.
- ONLYSCI_QUAL	High SCI_QUAL & low ORG_CAP Explaining the relationship between scientist's quality and organizational capability.	A dummy variable; Taking the value 1 when SCI_QUAL =1 & ORG_CAP=0.
- ONLYORG_CAP	Low SCI_QUAL & High ORG_CAP Explaining the relationship between scientist's quality and organizational capability.	A dummy variable; Taking the value 1 when ORG_CAP =1 & SCI_QUAL =0.
- NOSCI_ORG_CAP	Low SCI_QUAL & Low ORG_CAP Explaining the relationship between scientists quality	A dummy variable; Taking the value 1 when ORG_CAP =0 & SCI_QUAL =0.

	and organizational capability;	
Controls		
FIRM SIZE	Firms size	Count variable, counting number of employees in firm.
FIRM ECO	Firms economic strength	Count variable, estimating the economic strength of firm.
PAT_TECH_SCO	Patents Technology Scope	Count variable, using the number of IPC-classes assigned in the patent.
SCI_COM	Patents Scientific Relation	Count variable, counting how many backward non patent related citations (scientific references) the patent has.
COMP_ENVI	Competitive environment of patented invention	Count variable, counting the number of X citations, the higher number of x-citations the more competitive environment.

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