R&D MANAGEMENT

How to create commercial value from patents: the role of patent management

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This article examines the relationship between patent management and indicators of a firm's financial and patenting performance. The empirical analyses are based on a sample of 158 technology-based firms from the United States and Germany across multiple industries. The results show that two important dimensions of patent management, specifically patent protection management and patent information management, are positively correlated with a firm's level of financial profitability and the strategic and financial impact of its patent portfolio. This implies that patent protection and information management are important managerial capabilities of the firm that determine the level of value it can create from patents. We further find that a firm's technology strategy moderates the relationship between patent protection management and firm performance; it does, however, not moderate the relationship between patent information management and firm performance. Hence, the effectiveness of certain managerial capabilities on value creation from patents are contingent upon specific boundary conditions. Our findings have implications for improving firm performance through patent management.

1. Introduction

The pressure to innovate and to generate satisfactory financial returns from innovation prompted the rediscovery of intellectual property (IP) rights, particularly patents, in many firms across multiple industries (OECD, 2006; Di Minin and Faems, 2013; WIPO, 2013). An increasing number of firms has adopted proactive IP strategies and invested heavily in setting up a formal IP management organization (Cukier, 2005; Di Minin and Faems, 2013). A primary motivation for patent rights management is to obtain a temporarily exclusive market position by avoiding or, at least, postponing the imitation of innovations by competitors (Cohen et al., 2000; Cukier, 2005; Al-Aali and Teece, 2013). Additional motives include the external commercialization of a firm's existing patent portfolio to generate additional financial returns, for example, by means of licensing (Arora and Ceccagnoli, 2006), and gaining access to technological knowledge outside the firm, for example, by using patents as strategic assets to cross-license technology or to establish research and development (R&D) alliances (Grindley and Teece, 1997; Cukier,

2005). This increased strategic focus on IP has brought about a jump in the number of worldwide patent applications (WIPO, 2013).

In this environment of enhanced IP awareness, a central question for scholars and executives is the following: Does the increased investment of firms in patents pay off economically? Past empirical research fails to provide a satisfying answer to this question. Empirical studies have found at best only a weak positive relationship between the level of a firm's patenting activities and financial performance (Narin et al., 1987; Griliches et al., 1991; Ernst, 2001). After an extensive review of the literature, Gilbert (2006, p. 191) concludes that 'Unfortunately, the correspondence between patents and useful new products or processes is weak in many industries.' This raises the central question if existing economic models focusing on patent counts and relating these to several indicators of innovation activity and firm performance are sufficient to understand the value creation through patents. After reviewing the existing literature on the patenting-performance link, Levitas and Chi (2010, p. 213) came to the conclusion that 'the ambiguity left by existing studies on this theoretically important relationship [between patenting and performance (authors)] suggests that a closer look at both the theoretical reasoning behind this relationship and the design of empirical studies testing the relationship is warranted.' In line with this argument, we suggest to look beyond patent counts and to focus on the firm's managerial capabilities that are required to create significant commercial value from patents.

Case-based observations of firms suggest that the way a firm manages its patent portfolio rather than the simple size of the patent portfolio determines the amount of value created by patents (Cukier, 2005; Al-Aali and Teece, 2013; Di Minin and Faems, 2013). Recent work has echoed this notion and points to the importance of certain managerial capabilities firms need to possess to create value from their patents and to increase overall performance (Reitzig and Puranam, 2009; Somaya, 2012). Research has only begun to better 'understand how firms develop and employ the required managerial capabilities and how these capabilities in turn affect firm performance in the patent domain' (Somaya, 2012, p. 1101). Relevant managerial activities with regard to patents include the formulation and execution of an IP strategy, the establishment of an effective IP organization and efficient IP management processes, the integration of IP activities with other functional departments, especially with R&D, and the enforcement of IP rights (Cukier, 2005; Specht et al., 2006; Gassmann and Bader, 2011; Conley et al., 2013). A survey among 66 US firms found significant variations across companies concerning their management of patents (Cockburn and Henderson, 2003). Cockburn and Henderson (2003) assume that these differences impact the amount of value firms generate from their patents, and they call for more research on this issue. Existing economic models addressing the impact of patents on value creation in firms do not account for these managerial variations (Gilbert, 2006; Somaya, 2012). To our knowledge, a large-scale empirical study that links these varying patent management practices to firm performance does not yet exist. Results from such a study promise to conceptually advance research beyond its current focus on patent counts to a more managerial perspective of value creation through patents.

The initial step in this direction is the development of a theoretical model that conceptually defines patent management and links it to firm performance. This model should further include certain boundary conditions or contingencies under which patent management impacts performance. As Levitas and Chi (2010, p. 230) put it: 'Patenting itself doesn't necessarily create value; rather, firms must develop a deeper understanding of the conditions under which patent pursuit adds and possible subtracts value'. To our knowledge, a theoretical model that links patent management with firm performance while incorporating moderators of that link does not yet exist in the literature. This study addresses these open research questions and makes the following theoretical and empirical contributions: we develop a theoretical framework linking patent management, moderators and firm performance at the firm level. We test this framework empirically based on a sample of 158 US and German firms from multiple industries. We develop and validate new scales for measuring patent management activities in firms. We further use multiple indicators of performance to test on which dimension of performance patent management has an effect on and on which it has not.

2. Theory and hypotheses

2.1. Patent management and performance

The significance of patent management can best be understood in the broader context of technology management. The effective and efficient management of technology is essential for the financial performance of a firm because technology has a great impact on the competitiveness of firms (Porter, 1985). The fundamental objective of technology management is to maximize the economic returns from R&D investments (Burgelman et al., 2008). From a process

Table 1. Contributions of patent management to technology management

	Technology creation	Technology use
Internal Technology Creation and Use	**Field I** *Information* Function: Support for R&D Investment Decisions (Competitor Monitoring and Technology Assessment)	**Field II** *Information* Function: Identification of Patent Infringers and Patent Activity Limiting the Effectiveness of the Firm's Patent Position *Protection* Function: Effective Protection of Products from Imitation
External Technology Creation and Use	**Field III** *Information* Function: Identification and Assessment of Sources for External Technology Creation (e.g., M&A, Alliances) *Protection* Function: Access to External Knowledge (e.g., Cross-Licensing)	**Field IV** *Information* Function: Identification and Assessment of External Technology Users *Protection* Function: External Value Maximization of the Patent Portfolio (e.g., Out-Licensing)

perspective, technology management can be defined as the management of the internal and external creation and use of technological knowledge (Argote et al., 2003). Fundamentally, patent management supports this process of technological knowledge creation and use (see Table 1).

The contribution of patent management to technology management builds on the two fundamental functions of patents: protection and information. First, inventions filed at the patent office that fulfill the legal requirements are granted by the patent authorities. A granted patent gives the patent owner the right to exclude competitors and all others from using the invention (Chisum et al., 1998). In theory, a granted patent protects the patent owner, at least for a certain period of time, from imitation. This is what we define as the *protection function* of patents. Second, the information contained in the patent application, where the invention is disclosed, becomes publicly available 18 months after filing. The use of information disclosed in published patent documents is what we define as the *information function* of patents.

The managerial activities aimed at supporting and leveraging the protection function of patents are referred to as *patent protection management*. These include multiple organizational, procedural, and strategic actions managers can take to build a strong portfolio of patents which can be leveraged in various ways (Specht et al., 2006; Gassmann and Bader, 2011; Somaya, 2012; Conley et al., 2013). In the framework of technology management, patent protection management supports the process of technology creation and use in three important ways (Table 1, protection function): First, patent protection management supports the internal use of technological knowledge (see Field II in Table 1). The establishment of an effective patent portfolio helps a company to secure an exclusive competitive advantage for their new products in the marketplace. This unique competitive position leads to better firm performance because the firm can generate higher sales and profit margins. Second, patent protection management supports the external creation of technological knowledge (see Field III in Table 1). Strong patents create options for firms to get access to external technological knowledge. Firms can engage in cross-licensing or patent pooling activities if they can offer an attractive patent portfolio in exchange (Grindley and Teece, 1997). Similarly, the probability of forming an R&D alliance and its outcome often depend on the quality of patents brought into the alliance by the respective partners (Stuart, 2000). Third, patent protection management supports the external use of technological knowledge (see Field IV in Table 1), for example, by licensing patents (Lichtenthaler, 2006). IBM earns approximately US$1 billion annually from licensing, and HP quadrupled its licensing income to more than US$200 million in three years (Cukier, 2005).

Summing up, patent *protection* management improves the management of technology about the internal use, the external creation and the external use of technology (see Table 1). More specifically, an effective patent protection management helps a firm to better protect its innovations, to avoid infringements and to secure the freedom to operate. That strengthens a firm's competitive position in the market and hence its overall performance. It also helps a firm to better leverage its patents externally through the acquisition of technology. This allows access to relevant technologies, for example, through cross-licensing, which is critical for a firm's offerings on the market. This creates strategic options and more

flexibility, which positively impacts a firm's competitive position. Building a strong patent portfolio through patent protection management is further the prerequisite for the successful external commercialization of a firms' existing technologies, for example, as a result of licensing. The external commercialization of existing technological knowledge increases the economic returns from the initial R&D investments. Overall, we argue that patent protection management supports the capability of a firm to better secure and exploit its investments into technologies. This increases the returns from these investments and hence firm performance. We, therefore, postulate the following hypothesis:

H1: *Patent protection management is positively related to firm performance.*

The intensity by which firms use technical, legal and strategic information derived from patent documents is referred to as *patent information management*. This construct is conceptually different from patent protection management because it captures those managerial activities that are aimed at collecting and using the information contained in patent data. This activity improves the quality of decision-making during the process of generating and using technological knowledge (see Table 1). More specifically, patent information management supports this process in four ways: First, it can improve the internal creation of technological knowledge (see Field I in Table 1; information function). Patent information can be used for competitor monitoring and technology assessment. Knowing about the competitors' R&D strategies and identifying the most promising technologies are important for a firm's decision on which technologies should be created by internal R&D (Brockhoff, 1992; Ernst, 2003). Empirical research shows that patent data are a useful early warning indicator of emerging technologies (Ernst, 1997). Firms have the opportunity to anticipate technological changes and to allocate R&D resources accordingly. Better strategic decisions regarding the use of a firm's R&D resources will positively impact the financial returns from R&D and hence overall firm performance (Burgelman et al., 2008). Second, patent information management can improve the use of technological knowledge (see Field II in Table 1). The use of patent information helps the firm to identify potential patent infringers. Patent infringement can be a very costly matter for those who infringe on patents, and it can create a significant amount of financial rewards for the patent owner. Patent analyses can further detect the patenting behavior of competitors aimed at restricting the effectiveness of a competing firm's patent position. The negative impact of a so-called 'patent flooding' strategy, where a competitor aims to build a patent wall around another firm's patents to restrict this firm's freedom to operate or to enforce a licensing or cross-licensing deal, can only be avoided by taking appropriate countermeasures. This requires the continuous surveillance of the competitor's patenting activities in order to react appropriately. Using the information function of patents to avoid patent infringements and to secure the freedom to operate strengthens the firm's competitive position which should lead to higher performance.

Third, patent information management supports the external creation of technological knowledge (see Field III in Table 1). Sources for the external creation of knowledge can be identified and assessed based on the analysis of patent information. Patent indicators can be used to identify leading inventors or firms in a specific technology field (Ernst et al., 2000). Patent portfolios can further be applied to assess if the technological positions of firms complement or substitute each other (Brockhoff, 1992; Ernst, 1998). This information has important implications for identifying appropriate M&A targets, R&D alliance partners or in-licensing opportunities (Stuart, 2000; Ernst, 2003). Overall, the use of patent information improves a firm's decision-making process concerning the identification, assessment and selection of multiple external technology acquisition opportunities. This should have positive effects on the return on investment of these acquisition decisions and hence overall firm performance. Fourth, patent information management also supports the external use of technological knowledge (see Field IV in Table 1). The analysis of patent citation patterns or technological landscapes, for example, helps to identify licensing opportunities (Rivette and Kline, 2000; Arora and Ceccagnoli, 2006). Using the information function of patents can therefore increase the financial returns from a firm's out-licensing activities.

To sum up, patent *information* management improves technology management with respect to the internal and external creation and use of technology (see Table 1). Fundamentally, we argue that it provides important information that enhances the quality of strategic decision-making in technology management. These include, for example, R&D portfolio investment decisions and decisions regarding internal vis-à-vis external R&D investments. Better decision-making increases the commercial returns from R&D investments and hence firm performance. Patent information management further provides valuable insights, for example, about the infringement of patents. This is important for strengthening and defending the firm's patent position and securing freedom to

operate in the market. This improves a firm's competitive position and hence its performance. Lastly, the use of patent information enables decision-makers to identify and to assess additional business opportunities, for example, attractive options to commercialize existing technologies via out-licensing. This should further increase the returns from investing in new technologies. Overall, we postulate the following hypothesis:

H2: *Patent information management is positively related to firm performance.*

2.2. The moderating effect of technology strategy

We follow the notion expressed in the literature that the effect of patent management on performance is contingent upon certain boundary conditions (Levitas and Chi, 2010), that is, certain patent management capabilities are likely to be more relevant for value creation under specific conditions than others. Potential boundary conditions can be grouped into technology-, firm-, and industry-specific factors. Technology-specific contingent factors include, for example, the stage of the life cycle, the level of novelty or the degree of technological change. The effectiveness of patents is lower in areas that exhibit fast technological change (Grindley and Teece, 1997). Hence, patent management should have a weaker impact on performance when technological turbulence is high. Firm-specific factors include aspects such as firm size, the level of R&D expenditures, or a firm's technology strategy. The respective industry, the competitive intensity, or market dynamics are important industry-specific factors that can potentially moderate the patent management performance link.

We focus on a firm's technology strategy as the key moderating variable for the following reasons: First, the type of technology strategy is an important strategic choice of a firm with fundamentally positive and also potentially negative consequences for the firm (Bower and Christensen, 1995; Burgelman et al., 2008). Understanding the interrelations between a chosen technology strategy and the right patent management in order to enhance the overall economic performance of the firm is, therefore, of vital importance for academics and managers. Second, managers can choose the right combination of technology strategy and patent management in order to influence outcomes whereas the firm can only adapt to external technology- and industry-specific developments. We therefore believe that this managerially important aspect should be in the research focus. Third, we chose to conduct our study at the firm level which requires using firm-level variables such as technology strategy as a moderating variable and others as control variables.

Firms can follow different technology strategies. In line with prior research, we define a firm's technology strategy as its general strategic orientation about the use of technology for achieving a competitive advantage (Gatignon and Xuereb, 1997). Fundamentally, we aim to capture if a firm pursues a strategy of technological leadership aiming at launching the latest technologies ahead of the competition from a strategy of technological followership where a firm follows the technological developments in its industry with a significant time delay. We believe that the type of technology strategy pursued by the individual firm represents an important firm-specific boundary condition that impacts the relationship between patent management and performance.

Leading firms take a higher financial, technical and market risk when developing and launching new products based on new technologies. The technical risk is higher because the firm can hardly build on the experiences of others. The market risk is also higher because the new technology may not be accepted at the market or the market needs to be developed which takes more time and requires the investment of a significant amount of resources. Overall, the financial risk is higher because R&D investments and market development expenses are typically much higher for pioneering firms. Firms that lead the technological development in their industries, therefore, need to protect their innovations against fast imitation employing a strong patent portfolio to secure a monopolistic position and to realize satisfactory financial returns from their R&D investments (Cukier, 2005; Al-Aali and Teece, 2013). This can be achieved through patent protection management. Patent protection management should, therefore, have a much stronger impact on performance in case the firm pursues a strategy of technological leadership. On the contrary, patents play a less significant role in firms that follow the technological advances in their industry and aim at achieving competitive advantage by means other than technological leadership. Even if they file for patents, their significance is less because followers take a much lower financial risk compared to technology leaders. Thus, achieving a monopolistic position on the market is less critical for technology followers. Patent protection management is therefore of lower importance for performance for firms that follow technological changes. Overall, we argue that a technology leadership strategy should positively moderate the effect of patent protection management on firm performance. Hence, we postulate:

H3: *The more a firm pursues a strategy of technology leadership, the stronger is the relationship between patent protection management and firm performance*.

Concerning the moderating effect of technology strategy on the relationship between patent information management and performance, we need to distinguish two aspects. On the one hand, leading firms operating at the cutting edge of technological development need to be fully aware of emerging technologies and the associated proprietary positions. The failure to proactively respond to new and disruptive technologies can threaten the position of formerly dominant firms (Bower and Christensen, 1995; Ernst, 1997). The information contained in patent data can be an effective early warning indicator for upcoming new technologies (Ernst, 1997). The retrieval and analysis of this information from patent data, as the key task of patent information management, is therefore relevant for companies that pursue a strategy of technological leadership.

On the other hand, patent information can be of high relevance for technology followers too. Since these firms follow the technology development, they need to monitor their competitors' patenting activities to better understand their strategy and to find a way to imitate the pioneer's technology without infringing on their patents. This requires a careful analysis of competitors' patents, which is the primary task of patent information management.

To sum up, we expect patent information management to be an activity useful to both technology leaders and followers. Thus, we posit the following hypothesis:

H4: *Technology leadership does not moderate the relationship between patent information management and firm performance*.

3. Methods

3.1. Sample and data collection

During the pre-test phase, it became apparent that the large majority of firms were reluctant to provide us with the required information. Most of the firms consider this data as extremely confidential and were not willing to share this unless a relationship of trust could be established. We therefore had to refrain from the classic data collection approach and had to strongly rely on personal contacts. The first two authors have years of experience and a large industry network in the field of IP. Companies that had known the two authors for some time were willing to provide the required data. We therefore decided to rely on our personal contacts to recruit the sample. We called each firm, and we either spoke to the CEO (in the case of a smaller firm), the CTO/Director R&D or the VP/Director IP. If the contact person agreed to participate, we sent him or her the questionnaire. Multiple reminder phone calls were made to ensure that the questionnaire was filled out and sent back to the authors. Prior to conducting the actual survey, we had pretested the questionnaire thoroughly with senior IP managers from 20 companies in the United States and Germany. Typically, our first contact person was also the informant who filled out the questionnaire. Thus, the informants were predominantly either the vice president or director IP, the vice president or director R&D or members from top management in the case of smaller firms. All of the respondents had the unique knowledge to answer all questions and the authority to access the required information because of their high hierarchical position in their organizations. The data was collected in 2003 and 2004. In this time frame, no unusual external events such as significant macroeconomic developments occurred that may have impacted the data collection process. Patents and their management had already received significant attention in firms in these days (see e.g., Cukier, 2005). The importance of patents and their effective management have further increased until today (see e.g., Di Minin and Faems, 2013). It is, therefore, reasonable to assume that the conditions for firms with respect to the management of patents has not fundamentally changed from the time of data collection until today. However, one may suspect that its significance today may even be higher than what it used to be at the time of data collection. We offered a customized benchmarking report and an executive management summary as incentives for firms to participate in this study.

The sample consists of 158 companies from the United States (64 firms) and Germany (94 firms) covering multiple industries including life sciences ($n = 43$), chemicals and materials ($n = 26$), mechanical engineering ($n = 31$), electrical engineering ($n = 23$), communication, computers and software ($n = 14$), and others ($n = 21$). Technology and patent protection are important in these firms. The average amount of R&D expenditures as a percentage of sales amounts to 32.17% (SD = 94.51%). The high R&D intensity and the high standard deviation in the sample are caused by firms from the life science industry, which include a number of biotechnology firms. The average propensity to patent (share of patentable inventions for which patent applications are actually filed) is 63.09% (SD = 30.31%). The high standard deviation for the propensity to patent indicates that patent behavior varies substantially among the sample firms.

3.2. Measures

3.2.1. Patent management

We could not draw from prior research for a measure of patent protection and information management. We therefore developed a new scale in a two-step approach: First, we identified relevant variables by screening the existing literature on patent management (Granstrand, 2000; Teece, 2000; Specht et al., 2006; Gassman and Bader, 2011; Somaya, 2012; Ernst and Fischer, 2014). Second, we conducted in-depth interviews with 12 senior IP managers from different firms across various industries. This process helped us to develop a detailed understanding of the key aspects considered relevant by academics and practitioners for assessing patent management activity in a firm. Concerning the patent protection management construct, we asked our experts to identify especially those aspects that are critical for building and defending a patent portfolio, which captures the notion of 'protection' in our focal construct. We measured all items on a 5-point Likert scale with 1 (totally disagree) and 5 (totally agree) as the anchor points. We used exploratory factor analysis (key statistical indicators: KMO = 0.79, significance of Bartlett-Test = 0.00, communalities > 0.45, explained variance = 65.76%, factor loadings > 0.64) to reduce the items into two dimensions of patent management activity (an additional confirmatory factor analysis confirmed the results): patent protection management (Cronbach's alpha = 0.72) and patent information management (Cronbach's alpha = 0.87).

Furthermore, we checked for discriminant validity of both patent management constructs according to the procedure suggested by Fornell and Larcker (1981). Discriminant validity is given when the square root of the average variance extracted ($\sqrt{}$AVE) for each factor exceeds the correlations with all other factors. This was the case for all constructs. This illustrates that the constructs 'patent protection management' and 'patent information management' are conceptually and empirically two distinctively different dimensions of patent management. Patent protection management consists of items that measure the capability of a firm to protect and to defend its R&D investments through patents. The construct includes aspects such as the level of formalization of patent-related processes, the integration of patenting activities with R&D and the active pursuit of patent infringements. The patent information management construct measures the intensity by which firms use technical, legal, and strategic information derived from patent documents. The specific items measuring both constructs are listed in the Appendix.

3.2.2. Technology strategy

We developed a new construct measuring the overall importance of technology in the strategic orientation of the firm (Gatignon and Xuereb, 1997). The construct 'technology strategy' measures the degree to which a firm pursues a proactive technology strategy at the cutting edge of technology development vis-à-vis a more reactive technology strategy following the technological pioneers. The construct 'technology strategy' (Cronbach's alpha = 0.73) consists of four items. All items such as, for example, 'our products are always state-of-the-art in our industry', and 'we are known in our industry as being the first to introduce a new technology', were measured on a 5-point Likert scale with 1 (totally disagree) and 5 (totally agree) as the anchor points (see Appendix).

3.2.3. Performance

We used various multiple metrics to measure multiple aspects of firm performance. First, we used a firm's average profit margin of business-related sales. This provides a measure of financial performance that is not distorted by non-business-related activities. We chose this quasi-objective performance measure, because it is superior to the subjective assessment of firm performance by informants. This reduces a common source bias. Due to this focus on objective performance data, the number of observations for the empirical analyses were reduced, because some firms refused to provide their profit margins for confidentiality reasons.

Second, since profit margins may not capture all aspects of a firm's overall level of profitability and given our objective to increase the number of observations for the empirical analyses, we used a firm's annual sales growth as an additional indicator of performance. Sales growth (in %) was measured in the year the survey was conducted relatively to sales growth in the last three years prior to the investigation.

Third, we also capture a performance dimension that is conceptually closer to our patent management constructs. We therefore built the multi-item construct 'patent impact'. Patent impact measures multiple ways in which patents can be useful to the firm (Granstrand, 2000; Teece, 2000; Cockburn and Henderson, 2003; Specht et al., 2006; Gassman and Bader, 2011). We asked respondents to assess the following four aspects of usefulness: 'Our patents helped us for (a) accessing important technologies (e.g., by means of cross-licensing), (b) attracting strategic partners, (c) attracting investors, and (d) constraining competitors'. All four items were measured on a 1 (do not at all agree) to 5 (strongly agree) scale. The Cronbach's alpha coefficient for the construct 'patent impact' is 0.69.

Table 2. Means, standard deviations, and correlations (Max $n = 77$)

	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Patent Expenditures	6.98	10.42							
(2) R&D Intensity	10.62	14.00	0.09						
(3) Firm Size	14.823	41.161	−0.14	−0.14					
(4) Patent *Protection* Management	3.48	0.73	0.13	0.01	0.13				
(5) Patent *Information* Management	3.06	0.95	−0.36**	−0.10	0.03	0.26*			
(6) Technology Strategy	3.71	0.77	0.17	0.16	−0.15	0.37**	−0.01		
(7) Active Patents	53.09	28.85	0.00	0.22^{+}	0.21^{+}	−0.02	−0.10	0.08	
(8) Firm Performance (Profit Margin)	9.89	6.56	−0.14	0.18	−0.06	0.51**	0.46**	0.13	−0.02

$N = 71$–77 firms (N varies due to missing values).
**Significant at the 0.01 level.
*Significant at the 0.05 level.
+Significant at the 0.10 level.

3.2.4. Controls

Variables that can potentially affect the predicted relationships were used as control variables. These include the number of employees as a measure of firm size, the level of R&D expenditures as percentage of sales (R&D intensity) as a measure of a firm's emphasis on technology and innovation, dummy variables for firms from the United States and Germany, and dummy variables for the respective industries.

We further included the amount of money firms spend annually on all their patent-related activities (patent expenditures in Mio. US $/EUR) as a control variable. Firms could simply afford to invest more resources in establishing a more efficient patent management system. We can explicitly test, if the amount of a firm's resources devoted to patents impacts the predicted relationships in our conceptual model.

Finally, we use the '% of actively used patents (active patents)' as a control variable. The higher the '% of actively used patents' (active patents) is, the more focus the firm has overall on patents. Active patents are considered to be the most valuable patents a firm owns, because firms only keep patents alive in case they generate value to the firm that justifies the continuous payment of patent renewal fees (Schankerman and Pakes, 1986).

4. Results

Since we have different samples for the analyses depending on the respective dependent variable, we *first* present the results for the dependent variable profit margin ($n = 77$ firms that provided this very sensitive information). Table 2 shows means, standard deviations and correlations between the variables and constructs used to analyze this subset of data. Large firms use patents more actively than smaller firms. Higher R&D intensities are positively related with higher amounts of active patents. The type of technology strategy is significantly related to the level of patent protection management, however, not to performance. Also, the number of active patents is unrelated to profitability. Significant correlations between our focal patent management constructs and the level of profitability already suggest that patent management activities have an impact on performance.

We used OLS regressions to test our hypotheses. Low variance inflation factors (< 2.55) indicated that multicollinearity does not cause severe problems for the parameter estimates (Hair et al., 2010). We find a statistically significant and positive relationship between patent protection management and firm performance (profitability; see Table 3). This finding confirms H1. In addition, we also find a statistically significant and positive relationship between patent information management and performance (profitability; see Table 3). This result supports H2.

Moderated regression analyses are impossible due to very high correlations between the moderator variable, the interaction term and the main construct. We therefore used a simpler and robust approach to testing for moderation. We split the sample into high/low for our patent management and the technology strategy constructs. We used the median value to make the splits. We used ANOVA and the post hoc Scheffé-Test to analyze significant differences between the four groups. Tables 4 and 5 illustrate the results.

If firms change from a re-active (follower) to a pro-active (leader) technology strategy, higher levels of patent protection management increase performance (moderation as suspected in H3 at the higher end of a technology leadership strategy; see Table 4). If firms pursue a re-active technology strategy, higher levels of patent protection management also increase performance (moderation not as expected at the lower end of a follower strategy opposite to H3). This is a more differentiated finding with regard to H3.

The findings further show that patent information is important for leaders as well as for followers (see Table 5), however, it seems to be even more important for technological followers. This result leads to a more pronounced finding with regard to H4.

Second, we conducted similar analyses for the dependent variable 'sales growth'. We found that the level of patent protection and information management did not impact sales growth. Additional cross-checks with other indicators of profitability (e.g., profit margin of patent-protected products, share of patent-protected products of firm's total profits, impact of patent loss on the firm's profits) and sales growth (share of patent-protected products of firm's total sales, share of patent-protected products of firm's sales growth, impact of patent loss on the firm's sales) show for our data consistently that patent management affects a firm's level of profitability rather than its growth. This result indicates that growth can be achieved even without patents, if the growth opportunity exists. Patents matter more in a competitive situation, because they help firms to charge higher prices through differentiation from competitors. This result adds a more fine-grained implication, that is, on which dimension of financial performance patent management has an effect on, and on which it has not.

Table 3. OLS regression analyses: patent management and firm performance (profitability)

Independent variables	Dependent variable
	Firm performance (Profit margin)
Constant	0.00 (0.10)
Patent Expenditures	−0.10 (0.12)
R&D Intensity	0.23 (0.12)$^{+}$
Firm Size	−0.22 (0.12)$^{+}$
Germany	−0.10 (0.12)
Life Sciences	−0.07 (0.15)
Chemicals/Materials	−0.08 (0.14)
Mechanical Engineering	−0.24 (0.16)
Electrical Engineering	−0.16 (0.15)
Computer/Software	−0.11 (0.14)
Technology Strategy	−0.10 (0.11)
Active Patents	−0.04 (0.11)
Patent *Protection* Management	0.48 (0.12)**
Patent *Information* Management	0.28 (0.12)*
Adjusted R^2	0.36
F	3.83**
N	77

Regression coefficients (standard errors in parentheses).
$n = 77$.
**Significant at the 0.01 level.
*Significant at the 0.05 level.
+Significant at the 0.10 level.

Third, we present the results for the dependent variable 'patent impact' ($n = 82$). Table 6 shows means, standard deviations and correlations between the variables and the constructs used to analyze this subset of data. Firms with high R&D intensities, higher levels of patent expenditures, higher patent management activities and a more proactive technology strategy have a patent portfolio with a greater impact (see Table 6).

We used OLS regressions again to test our hypotheses. Low variance inflation factors (<2.17) indicated that multicollinearity does not cause severe problems for the parameter estimates (Hair et al., 2010). We find a statistically significant and positive relationship between patent protection and patent information management and patent impact (see Table 7). Patent protection and information management, therefore, affect a performance measure that is closer to a firm's patenting behavior, that is, patent impact. This finding reconfirms the core finding of the article, that is, patent protection and information management are core enablers of value creation through patents (see H1 and H2).

Due to very high correlations between the moderator variable, the interaction term and the main construct, we again split the sample into high/low for our patent management and the technology strategy constructs. We used the median value to do the splits. We used ANOVA and the post hoc Scheffé-Test to analyze significant differences

Table 4. Moderation analyses: patent protection management, technology strategy, and firm performance (profit margin)

		Technology Strategy	
		Follower	Leader
Patent Protection Management	High	I. 13.86 ($n = 13$)	III. 12.48 ($n = 22$)
	Low	0. 7.29 ($n = 28$)	II. 6.65 ($n = 11$)

Mean values and sample size reported per group. The median (3.75 for technology strategy and 3.5 for patent protection management) was used to split sample into high and low. ANOVA shows that firm performance differs significantly ($P = 0.001$) between all four groups.
Scheffé-Test shows the following differences between specific groups (level of significance in parentheses): 0. vs I. ($P = 0.017$); 0. vs II. (n.s.); 0. vs III. ($P = 0.031$); I. vs II. ($P = 0.040$); I. vs III. (n.s.); II. vs III. (0.080).

Table 5. Moderation analyses: patent information management, technology strategy, and firm performance (profit margin)

		Technology strategy	
		Follower	Leader
Patent Information Management	High	I. 12.24 (n = 22)	III. 11.43 (n = 15)
	Low	0. 5.78 (n = 20)	II. 9.79 (n = 18)

Mean values and sample size reported per group. The median (3.75 for technology strategy and 3.0 for patent information management) was used to split sample into high and low. ANOVA shows that firm performance differs significantly ($P = 0.008$) between all four groups.
Scheffé-Test shows the following differences between specific groups (level of significance in parentheses): 0. vs I. ($P = 0.014$); 0. vs II. (n.s.); 0. vs III. ($P = 0.077$); I. vs II. (P = n.s.); I. vs III. (n.s.); II. vs III. (n.s.).

Table 6. Means, standard deviations, and correlations (Max. $n = 82$)

	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Patent Expenditures	6.90	10.49							
(2) R&D Intensity	36.00	124.87	0.49**						
(3) Firm Size	18.398	43.711	−0.15	−0.10					
(4) Patent *Protection* Management	3.51	0.80	0.09	0.13	0.21+				
(5) Patent *Information* Management	2.92	1.77	−0.17	−0.08	0.12	0.35**			
(6) Technology Strategy	3.80	0.71	0.29**	0.15	−0.17	0.30**	−0.11		
(7) Active Patents	55.81	31.49	0.19	0.18	−0.14	0.07	−0.13	0.21+	
(8) Patent Impact	2.99	0.93	0.22+	0.24*	0.17	0.52**	0.33**	0.29**	0.09

$N = 75$–82 firms (N varies due to missing values).
**Significant at the 0.01 level.
*Significant at the 0.05 level.
+Significant at the 0.10 level.

between the four groups. Tables 8 and 9 illustrate the results.

The construct 'technological strategy' does not moderate the relationship between patent information management and patent impact. This confirms H4.

5. Discussion

The findings of our study indicate that patent management is positively and significantly related to multiple dimensions of firm performance. This illustrates that not the size of a firm's patent portfolio but rather the way a firm manages its patent portfolio determines the amount of value created by patents.[1] Since prior empirical research has neglected this managerial aspect, it is now evident why it has failed to link patent counts with firm performance. Our findings imply that we should adopt a managerial perspective to better understand the drivers of value creation through patents in firms. Patent management is therefore a critical managerial capability a firm needs to possess to capture value from its patents (Somaya, 2012).

The empirical findings support our conceptual reasoning why patent management is a critical capability. Patent management improves technology management in multiple ways and therefore increases the financial returns from R&D investments. We distinguished conceptually the two main functions of patents, that is, protection and information. The empirical findings show that both dimensions of patent management matter for firm performance. Patent protection management establishes a strong patent portfolio, which can be leveraged in the following ways: to better protect product innovations from imitation in the marketplace and thereby increasing profitability and growth and to better leverage patents outside the firm, for example, to access external technologies or attracting partners and/or investors.

Whereas this protection function of patents has received increased recognition by academics and managers, the opportunities of using a patent's information function have not yet been fully recognized. We have shown conceptually that patent information management improves technology management in multiple ways. Patent information improves the quality of decision-making in important fields of technology management, that is, R&D portfolio decisions, decisions to acquire technology from external sources and decisions to commercialize technology outside the firm. Patent information is, in theory, relevant for

technology management, and our findings lend validating empirical support for this basic proposition. Researchers and managers can benefit by recognizing this and focus more on patent information management. Managers find tools and methods to improve the way patent information is used in technology management (Ernst, 2003).

Concerning the moderating effect of technology strategy on the relationship between patent information management and performance, we found no effect for the patent impact construct. Patent information management is therefore a useful activity for technology leaders as well as followers when it comes to building a strong and useful patent portfolio. Concerning profitability, patent information management seems to be more relevant for followers. Business performance of technological followers depend more on their capability to systematically monitor technological changes in order to respond timely and adequately to these changes whereas leaders seem to pro-actively shape new technologies where patent monitoring may be less critical. These results help to understand in more detail under which conditions patent information management is relevant with regard to multiple performance dimensions.

Table 7. Multiple regression analyses: patent management and patent impact

Independent variables	Dependent variable
	Patent Impact
Constant	0.00 (0.10)
Patent Expenditures	0.14 (0.13)
R&D Intensity	0.09 (0.12)
Firm Size	0.18 (0.11)$^{+}$
Germany	−0.10 (0.11)
Life Sciences	0.34 (0.14)*
Chemicals/Materials	0.28 (0.12)*
Mechanical Engineering	0.25 (0.12)*
Electrical Engineering	0.22 (0.12)$^{+}$
Computer/Software	0.17 (0.13)
Technology Strategy	0.14 (0.12)
Active Patents	−0.03 (0.10)
Patent *Protection* Management	0.34 (0.13)**
Patent *Information* Management	0.25 (0.11)*
Adjusted R^2	0.36
F	4.09**
N	82

Regression coefficients (standard errors in parentheses).
**Significant at the 0.01 level.
*Significant at the 0.05 level.
+Significant at the 0.10 level.

Concerning the moderating effect of technology strategy on the relationship between patent protection management and performance, we find, on the one hand, support for our initial hypothesis. Firms that pursue a proactive technology strategy require high levels of patent protection management to increase firm performance (profitability) and to create a high impact patent portfolio. The findings, on the other hand, also reveal that technological followers cannot afford to neglect patent protection management either. For these firms, increases in patent protection management activities yield strong and positive effects on performance (profitability) and patent impact too. This could be the case because followers have to make sure that they do not infringe upon the leaders' existing patents and manage to create a strong patent portfolio on their own, that secures a competitive advantage. That is a more difficult task compared to technology pioneers that do not face much prior art. That requires higher levels of patent protection management for technological followers that take on technology leaders. The current patent fight between Samsung (follower) and Apple (leader) is a good example for this (Fickling and Kelly, 2011). This finding sheds a more fine-grained light on the boundary conditions under which patent protection management impacts multiple performance outcomes. It also adds to the recent discussion and highlights that the effectiveness of certain patent management capabilities for value creation can depend on firm-specific contingent factors such as a firm's technology strategy (Somaya, 2012).

Table 8. Moderation analyses: patent protection management, technology strategy, and patent impact

		Technology strategy	
		Follower	Leader
Patent Protection Management	High	I. 3.32 ($n = 17$)	III. 3.39 ($n = 20$)
	Low	0. 2.36 ($n = 27$)	II. 3.08 ($n = 15$)

Mean values and sample size reported per group. The median (3.75 for technology strategy and 3.5 for patent protection management) was used to split sample into high and low. ANOVA shows that patent impact differs significantly ($P = 0.000$) between all four groups.
Scheffé-Test shows the following differences between specific groups (level of significance in parentheses): 0. vs I. ($P = 0.005$); 0. vs II. (0.070); 0. vs III. ($P = 0.001$); I. vs II. ($P =$ n.s.); I. vs III. (n.s.); II. vs III. (n.s.).

Table 9. Moderation analyses: patent information management, technology strategy, and patent impact

		Technology strategy	
		Follower	Leader
Patent Information Management	High	I. 2.77 ($n = 22$)	III. 3.56 ($n = 12$)
	Low	0. 2.69 ($n = 22$)	II. 3.09 ($n = 23$)

Mean values and sample size reported per group. The median (3.75 for technology strategy and 3.0 for patent information management) was used to split sample into high and low. ANOVA shows that patent impact differs significantly ($P = 0.037$) between all four groups.
Scheffé-Test shows the following differences between specific groups (level of significance in parentheses): 0. vs I. (P = n.s.); 0. vs II. (n.s.); 0. vs III. ($P = 0.070$); I. vs II. (P = n.s.); I. vs III. (P = n.s.); II. vs III. (P = n.s.).

The present study has limitations that offer opportunities for further research. First, the sample has some restrictions. We had to rely on personal contacts to create the sample for our study due to the reluctance of many firms to provide the required data. Our sample is therefore not representative for United States and German high-technology firms in a strict statistical sense. We have, however, no reason to believe that this approach fundamentally distorts our findings. We believe that the firms and industries surveyed are relevant and adequate for studying our research question. Due to the cross-sectional nature of our data, we cannot fully control for unobserved effects and establish causality. To address these problems we have used a large number of control variables. Also, we feel that we have strong theoretical arguments why patent management should impact performance and not v.v. Overall, however, we acknowledge that additional empirical efforts with larger and – if possible – panel data to analyze time-dependent effects are desirable to further validate our findings.

Second, we use a particular definition of patent management, focusing on the main functions of patents at an aggregate level of analysis. We suggest extending this work by refining or by adding new dimensions to our basic framework of patent management. This type of research is relevant because it would substantially increase our knowledge about further managerial aspects that determine the amount of value created by patents.

Third, our study has only explicitly incorporated one moderator as a boundary condition under which patent management impacts performance. The inclusion of other technology-, firm- or industry-specific moderating factors, for example, the degree of competitiveness or technological turbulence the firm is facing in its industry or the level of cross-functional integration (Ernst and Fischer, 2014), would help to identify further boundaries under which patent management impacts firm performance. This approach would allow for testing more complex interrelated models which shed more light on the relative importance of various boundary conditions for the patent management-performance link.

Fourth, the present study has focused on patents only. The management of other IP regimes, especially trademarks and copyrights, can also have an important impact on firm performance. It would, therefore, be intriguing for researchers and managers to analyze, similar to the conceptual model developed and applied in this article, antecedents of professional trademark or copyright management and its impact on firm performance. Looking at other IP regimes raises the question of IP integration, that is, the integrative management of multiple IP regimes to obtain the optimal competitive position in the marketplace. The integrative management of IP regimes over the product life cycle is especially important because the effectiveness of single IP regimes can vary over time (Conley et al., 2013).

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Note

1. It is plausible to assume that at least a minimum size of a patent portfolio should exist to make an effective patent management meaningful. We thank an anonymous reviewer for pointing this point.

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Appendix: Items, Constructs, and Reliabilities

A1. Patent Protection Management (4 items; $\alpha = 0.72$)

We pursue patent infringements consistently and promptly. We have a specific position or employee permanently designated as a point of contact for all questions regarding patents. Patent management is systematically integrated into the R&D process. Patent-related matters are dealt with formally in the organization. All four items were measured on the following scale: strongly disagree (1) to strongly agree (5).

A2. Patent Information Management (3 items; $\alpha = 0.87$)

How often do you analyze patent data to get a) technical information b) legal information (e.g., regarding patent infringements) or c) strategic information (e.g., regarding competitors, technological trends or licensing opportunities). All three items were measured on the following scale: never, yearly, every six months, monthly, weekly, and daily.

A3. Technology Strategy (4 items; $\alpha = 0.73$)

Our products are always state-of-the-art in our industry. We are known in our industry as being the first to introduce a new technology. We do not strive for technological leadership (reverse coded). We follow the technological developments of our competition with some time delay (reverse coded). All four items were measured on the following scale: strongly disagree (1) to strongly agree (5).

