Paper to be presented at the

35th DRUID Celebration Conference 2013, Barcelona, Spain, June 17-19

# Co-ownership of intellectual property: Exploring the value appropriation and creation implications of co-patenting with different partners


**Bart Leten**
KU Leuven
Managerial Economics, Strategy and Innovation
bart.leten@econ.kuleuven.be

**Rene Belderbos**
KU Leuven
Managerial Economics, Strategy and Innovation
rene.belderbos@kuleuven.be

**Bart Van Looy**
KU Leuven
Managerial Economics, Strategy and Innovation
bart.vanlooy@kuleuven.be

**Bruno Cassiman**
IESE Business School
Strategic Management Department
b.cassiman@iese.edu

**Dries Faems**
University of Groningen
Innovation Management and Strategy
d.l.m.faems@rug.nl



Abstract

Combining both qualitative data (interviews with IP managers) and empirical analysis at the patent and firm levels, we explore the value appropriation and value creation implications of R&D collaboration involving co-ownership of intellectual property (i.e. co-patents). We make an explicit distinction between three different types of co-patenting partners: firms active in the same industry, inter-industry partners, and universities. We find that the value appropriation liabilities of IP sharing are particularly strong for intra-industry co-patenting, where partners are more likely to compete in exploitation in their core domains. Co-patenting with universities is associated with increased market value, as appropriation challenges are unlikely to play a role and collaboration may signal novel technological opportunities. While there is weak evidence that co-patenting may increase (patent) value, patents co-owned with firms are significantly less likely to receive self-citations, indicating constraints in terms of future exploitation and development of co-owned technologies.

Jelcodes:O32,O34

# Co-Ownership of Intellectual Property: Exploring the Value Appropriation and Creation Implications of Co-Patenting with Different Partners

**Abstract**

Combining both qualitative data (interviews with IP managers) and empirical analysis at the patent and firm levels, we explore the value appropriation and value creation implications of R&D collaboration involving co-ownership of intellectual property (i.e. co-patents). We make an explicit distinction between three different types of co-patenting partners: firms active in the same industry, inter-industry partners, and universities. We find that the value appropriation liabilities of IP sharing are particularly strong for intra-industry co-patenting, where partners are more likely to compete in exploitation in their core domains. Co-patenting with universities is associated with increased market value, as appropriation challenges are unlikely to play a role and collaboration may signal novel technological opportunities. While there is weak evidence that co-patenting may increase (patent) value, patents co-owned with firms are significantly less likely to receive self-citations, indicating constraints in terms of future exploitation and development of co-owned technologies.

## INTRODUCTION

The open innovation paradigm conceives R&D as an open system, emphasizing that firms can benefit from a wide variety of collaborative activities with external knowledge sources (Chesbrough 2003, 2006). Scholars (e.g. Belderbos et al., 2004; Cassiman & Veugelers, 2006; Chesbrough, 2003; Faems et al., 2005; Laursen & Salter, 2006) therefore emphasize the need for inter-organizational collaboration as it allows for the synergistic blending of external and internal ideas into new products, processes and systems. At the same time, these scholars acknowledge the appropriation challenges such open innovation model entails. The more firms collaborate with external partners, the more difficult it becomes to appropriate the outcomes of such collaborative efforts across the different partners (Henkel, 2006; Chesbrough & Rosenbloom, 2002). Laursen and Salter (2005) therefore refer to the 'paradox of openness', emphasizing that 'the creation of innovations often requires openness and commercialization of innovations requires appropriability.'

In this paper, we focus on co-patenting as a potential window to investigate this openness paradox. In practice, co-patenting implies the joint ownership of collaborative outcomes. Existing research on this particular phenomenon emphasizes the disadvantages of co-patenting. Hagedoorn (2003), for instance, labels co-patenting as a second-best strategy that firms prefer to avoid. Belderbos et al (2010) find a negative relationship between the share of co-patents in firms' patent portfolios and firms' financial performance. At the same time, these studies provide evidence that co-patenting is not a fading phenomenon. The number of co-owned patents steadily increased in the USA between 1989 and 1998 (Hagedoorn, 2003) and the share of co-patents within patent portfolios of R&D intensive firms remained stable between 1996 and 2003 (Belderbos et al, 2010). This persistence appears partially a phenomenon at the firm level, as firms with experience in joint patenting are more likely to engage in joint patenting activities subsequently (Hagedoorn, Kranenburg and Osborn (2003).

In sum, whereas studies stress the disadvantages of co-patenting, one also observes that co-ownership of intellectual property (IP) remains an empirically relevant strategy for companies developing technology jointly. Given this observation, the purpose of this paper is to explore the role and performance implications of co-patenting in collaborative R&D activities. In particular, we focus on the potentially different implications of co-patenting with different types of partners, where we distinguish intra-industry, inter-industry and university partners. We proceed in two steps. In a first step, we conducted interviews with 10 IP managers from large organizations that engage in R&D collaboration and co-patenting on an international level. In general, these interviews confirm that co-ownership of IP might indeed restrict firms' ability to fully appropriate the market potential of knowledge that is generated in collaborative R&D. At the same time, they provide a richer understanding of the role and performance implications of co-patenting. First, interviewees suggested that the value appropriation liabilities of co-patents heavily depend on the type of partner involved in the collaborative activities. Second, our interview findings indicate that ex-ante negotiations of co-patenting arrangements may also create positive value creation dynamics within collaborative R&D.

In the second step of our study, we relied on panel data from 164 European, U.S., and Japanese firms to test some of the insights that emerged from our interviews. Our quantitative analyses show a significantly negative relationship between the share of co-patents with intra-industry partners and firm performance – which we measure as the growth in market valuation (Tobin's q). While co-patenting with inter-industry partners has no appreciable impact, co-patenting with universities increases market valuation. At the patent level, we observe a strong negative partial correlation between co-patenting with firm partners and focal firms' self citations to these patents, whereas a positive correlation is observed between co-patenting and other firms' citations. Together these results provide a more detailed perspective on the value appropriation consequences of co-patenting as these differ across types of partners. While it is possible that more value is created through these co-owned technologies, individual firms face liabilities in appropriating the returns to these technologies and in drawing on these technologies in their subsequent R&D and patenting efforts. In intra-industry partnerships, there is a high probability that partners have overlapping exploitation domains for co-owned technologies, which increases the risk that exploitation by one partner reduces appropriation opportunities for the other. In inter-industry partnerships exploitation domains are more likely to differ, while university partners are less likely to work on commercialization trajectories.

Jointly, these findings provide a more nuanced perspective on the role of co-patents in addressing the openness paradox in collaborative R&D activities. At the same time, we identify important avenues for future research on joint ownership of IP in open innovation settings, emphasizing the need to further explore both value appropriation and value creation implications of collaborative IP arrangements, and the importance of making an explicit distinction between co-patent ownership rights and exploitation rights.

In the next section, we rely on existing literature and our interviews to explore the role and performance implications of co-patenting. Section 3 discusses our data and methods. Empirical results are presented in Section 4 followed by a discussion and conclusion in Section 5.

## EXPLORING THE ROLE AND PERFORMANCE IMPLICATIONS OF CO-PATENTING

A co-patent is a patent where the ownership is shared by two or more assignees. As such, co-patent arrangements are clearly different from other multi-party patent arrangements such as cross-licensees, pooled patents, and patent infringement arrangements.[1] In case of co-patents, both applicants have the right to exploit the invention on their own behalf. At the same time, considerable differences can be observed between national patent offices in terms of transfer of ownership as well as license agreements. By default, co-patents within the USPTO imply considerable degrees of freedom for involved co-applicants: transferring ownership as well as engaging in license agreements does not imply consent of the other owners (35 U.S.C. 262 Joint

[1] See Hagedoorn (2003) for a discussion of the legal differences between co-patenting and other multi-party patent arrangements.

owners[2]). This means that, if company A and B are co-owners of a patent, company B has the right to license the patent to company C, potentially a competitor of company A, without needing consent of company A (Carlson & Barney, 1999; Paradiso & Pietrowski, 2009). The situation in this respect is different in Europe where consent in case of transferring ownership and/or engaging in license agreements is rule rather than exception.[3] Contractual agreements between partners can complement and alter the default arrangements between partners, both in terms of transfer of ownership and in terms of license agreements.

Both legal and management scholars have emphasized the complexities co-patenting entail (e.g. Hagedoorn, 2003; Paradiso & Pietrowski, 2009; Merges & Locke, 1990). At the same time, when inspecting the evolution of co-patenting intensity over time, one observes a steady increase of co-patenting which coincides with the overall growth rates of patent activity (Hagedoorn, 2003). As such, the proportion of co-patents remains relatively stable over time (Appio, Landoni & Van Looy, 2012; Belderbos et al., 2010). Moreover Hagedoorn et al. (2003) provide evidence that, when firms have engaged in co-patenting activities in the past, they are more likely to engage in co-patenting in later collaborative activities. These latter findings suggest that, despite the complexities and challenges of co-patenting, co-ownership of patented inventions is considered a viable option in particular circumstances.

As a first step in this study, we therefore conducted interviews with 9 IP experts operating in multinational firms and 1 IP expert of a knowledge institute with a strong international reputation. We asked interviewees to reflect on (i) the benefits and liabilities of co-patenting for collaborative R&D activities, and (ii) the potential performance implications of co-patenting. Subsequently, we systematically compared the content of the interviews with existing literature on co-patenting. In

---

[2] 'In the absence of any agreement to the contrary, each of the joint owners of a patent may make, use, offer to sell, or sell the patented invention within the United States, or import the patented invention into the United States, without the consent of and without accounting to the other owners.'

[3] AIPPI (2007) Summary Report: The impact of co-ownership of Intellectual Property Rights on their Exploitation.

line with existing research, the interviews clearly showed that co-patenting implies important value appropriation risks. At the same time, however, interviewees also indicated that ex-ante negotiation of co-patenting arrangements might affect value creation processes in collaborative R&D activities. Below, we discuss these two aspects of co-patenting in detail.

**Value Appropriation Implications of Co-Patenting**

Whereas single owned patents create a temporary monopoly for the patent owner, co-patenting resembles a duopoly (or tight oligopoly) in which the joint owners of the patent can compete against each other (Hagedoorn, 2003). In our interviews, it was acknowledged that, compared to fully owned patents, co-ownership of knowledge creates fewer opportunities for realizing monopoly rents. In addition, it was stressed that sharing ownership of knowledge 'creates uncertainty on the control that each co-owner has on the co-owned IP.' Several examples were provided to illustrate such value appropriation risks:

> 'Under Swedish law, a co-owner has the right to get rid of the patent and sell his part of the patent ownership. The other co-owner can bid for the rights, but the selling co-owner has the right to sell his ownership to the biggest bidder. This can be a competitor, who uses the patent to compete with the other co-owner.'

> 'There is always a risk that they [i.e. patent co-owner] will go bankrupt and their rights on the co-patents are sold.'

Prior research on the performance implications of co-patenting has largely ignored the type of partners involved in the co-patenting activities. Interviewees, however, emphasized that the presence of value appropriation liabilities of co-patenting heavily depends on the type of partner involved. First of all, they indicated that value appropriation concerns are likely to be low when ownership of knowledge is shared with universities. When the partner is a university, the risk that this partner can become a competitive threat for the focal firm is rather limited because universities often lack the incentives and abilities to commercially exploit the co-owned knowledge:

> ‘The business of universities is not to compete with companies. Universities are rather in the business of educating people, developing their faculty and doing basic research. Hence markets are likely less concerned when companies co-own patents with universities.’

In addition, interviewees stressed that, when they engage in collaboration with universities, ‘it is a standard procedure to contractually negotiate that universities do not have the right to license such co-owned knowledge to our competitors.’ In this way, firms can mitigate the risk that co-patenting with universities might indirectly trigger increased competition.

Regarding co-patenting with private firms, interviewees emphasized that the value appropriation consequences of co-patenting depend on whether partners are active in similar domains. In particular, it was stressed that, when partners are active in different markets there is a relatively high likelihood that they will use the co-owned knowledge for different exploitation purposes:

> ‘When we collaborate with suppliers, a standard agreement is that we get the right to exploit the IP within the application domain of our products, whereas the partner can exploit the IP in other domains that are outside our commercial interest.’

In contrast, when partners are active within the same industry, the risk that they will deploy the co-owned knowledge for similar purposes is higher, implying a risk of intensified competition which could jeopardize value appropriation.

> ‘Co-patents with competitors trigger difficult discussions [about exploitation] afterwards.’

Based on these insights, we expect that there are higher value appropriation liabilities to co-patents with intra-industry partners, where the risk of overlapping application domains is relatively high, than to co-patents with inter-industry partners or with universities. As information on co-patenting activities disseminates, investors and analysts are likely to take these consequences into account in their assessment of future profitability prospects. This implies that a negative impact of co-patenting on market valuation, which prior research has identified, should primarily be a feature of co-patenting activities with intra-industry partners.

**Value Creation Implications of Co-Patenting**

Our interviews also suggest that negotiating co-patenting arrangements ex ante might influence the collaboration processes and hence the actual value creation process resulting from this collaboration. First, following the open innovation paradigm, organizations that engage in collaborative R&D efforts have the opportunity to synergistically combine their complementary knowledge sources. This allows generating technological inventions that organizations could not realize on their own (Carson et al., 2003; Doz & Hamel, 1997; Vanhaverbeke, 2006). At the same time, it is stressed that, in order to effectively realize such synergies, intensive interaction between partners is necessary (Doz, 1996; Faems, Janssens & Van Looy, 2007). Existing studies on inter-firm R&D collaboration, however, signal that the willingness of partnering firms to engage in intensive interaction is often limited because of ex-ante knowledge appropriation concerns. Macho and Tallman (1998: 332), for instance, argue that 'such interaction acts as a double-edged sword since, in order to attain the underlying purpose of transferring, absorbing, and, generally, more effectively combining complementary capabilities at the heart of the collaboration, the firm also exposes critical resources and capabilities to transmission through the alliance to the partner firm.' In a similar vein, Heian and Nickerson (2004: 401) mention that intensive and fine-grained interaction 'increases the likelihood that economically valuable knowledge […] is expropriated.' In other words, these scholars – following a transaction cost logic – suggest that firms' ability to come to joint value creation in collaborative projects might be restricted because of ex-ante concerns that the other partner might opportunistically appropriate the knowledge that results out of such interaction.

In our interviews, IP experts referred to the importance of ex-ante contractual IP allocation procedures to mitigate such knowledge appropriation concerns. In particular, they described that, at the start of the collaboration, partners tend to contractually define the existing knowledge domains of both partners based on their existing technological expertise and capabilities. In addition, they contractually agree that, when collaborative R&D efforts result in intellectual property in one of these knowledge domains, the owner of this domain will become the sole owner of the patent. At the same time, several interviewees stressed the likely presence of a 'gray [knowledge] zone' where it is difficult to determine ex-ante who should be the owner of intellectual property. For these particular knowledge domains, interviewees pointed to the relevance of co-patenting arrangements, where partners contractually agree to share the ownership of knowledge that is jointly generated. This observation is in line with Hagedoorn' s (2003) argument that joint patenting is mainly relevant in 'inter-firm R&D collaboration where companies are unable to divide the inventions among partners.' Based on these observations, we expect that, when partners contractually define the option of co-patenting for knowledge domains that are non-partner specific, ex-ante knowledge appropriation concerns are mitigated, resulting in a higher willingness to effectively engage in joint value creation activities.

Interviewees also referred to the relational function of ex-ante co-patenting arrangements in collaborative R&D activities. Hagedoorn et al. (2003, p. 72) already argued that 'joint patenting expresses a mutual relational trust between separate companies.' In a similar vein, our interviewees stressed that co-patents might contribute to increased trust levels between collaborative partners, which might strengthen the intensity of cooperation between involved partners:

> 'Up-front co-patent arrangements are helpful because they reinforce the mutual commitment of both partners.'
>
> 'Co-patent arrangements provide a signal of trust which strengthens the connection between the partners and stimulates cooperation.'
>
> 'As a large company, we sometimes use co-patents to reduce the distrust of small partners. It is about creating goodwill and the necessary trust to increase the probability of collaborative success.'

In sum, we find strong indications that co-patenting arrangements might reduce ex-ante knowledge appropriation concerns and subsequently contribute to positive trust dynamics during the collaboration. In line with existing literature on collaborative R&D (Dyer & Singh, 1998; Cassiman & Veugelers, 2006; Faems et al., 2008), we expect that, in such circumstances, the willingness of partners to effectively combine their complementary knowledge will be higher, increasing the probability of effective joint value creation.

## DATA AND METHODS

We constructed a panel dataset (1996-2003) consisting of the technological activities of 164 R&D-intensive European, US and Japanese firms active in five -broadly defined- industries: (i) non-electrical machinery, (ii) pharmaceuticals & biotechnology; (iii) chemicals; (iv) IT hardware (computers and communication equipment); and (v) electronics & electrical machinery. The firms are drawn from the 2004 EU industrial R&D investment scoreboard, which provides listings of the most R&D-intensive European, US and Japanese firms across all industries. The firms are the largest R&D spenders in each industry and each of the three home countries/regions.

We rely on the firms' patents granted by the European Patent Office to examine co-patenting behaviour and to construct measures of technological performance based on patent value (citations). There are numerous advantages to the use of patent indicators (Pavitt, 1985; Basberg, 1987; Griliches, 1990; Hall et al, 2005): patent documents contain highly detailed information on content and ownership of patented technology; they cover a broad range of technologies; patent data are 'objective' in the sense that they have been processed and validated by patent examiners; and patent data are publicly available. Like any indicator, patents are also subject to a number of limitations: not all technological activities are patented; patent propensities vary across firms and industries.[4] Patented technological activities differ in their technical and economic value (Schankerman and Pakes, 1986; Albert et al., 1991; Harhoff et al., 1999). Patent forward citations have been advanced as a measure for the value of patents (e.g. Trajtenberg, 1990; Henderson et al., 1998; Hall et al., 2005). While forward patent citations are found to correlate positively and significantly with patents' economic value (Harhoff et al., 1999; Jaffe et al., 2000; Gambardella et al.,

[4] As reported by Levin et al (1987) and Arundel and Kabla (1998), patent propensities are high in our five sample industries, making patents a meaningful indicator of firms' technological activities in these industries.

2008) as well as firm value (Hall et al., 2005), they explain only part of the actual variance in the economic value of patents (Gambardella et al., 2008).

In this study, we used patent data from the European Patent Office (EPO). European patent data was preferred to the more commonly used data from the United States Patent and Trademark Office (USPTO). EPO patents are, typically, considered to provide a better indication of valuable technological activities: the cost of patenting is two to five times greater at EPO than at USPTO; the workload of patent examiners is four times smaller at EPO than at USPTO; and EPO has a 20-30% lower patent-granting rate than USPTO (Van Pottelsberghe de la Potterie and François, 2006; Quillen and Webster, 2001; Jaffe and Lerner, 2004). Since we are interested in IP sharing and appropriation, we focus our analysis on patent applications that are subsequently granted, and their citations. We classify patents by the year of application. Patent-granting decisions in the European Patent Office take 5-6 years on average, such that even for our time-frame of analysis (1996-2003) there is a degree of right truncation of patent counts.[5] We note that this does not have to affect citations received: since patent applications are published well before patents are granted[6], granted patents receive citations well before the grant date. We control for truncation by including year dummies for the application year of the patent in our empirical models. We apply a fixed 4-year window to calculate the number of citations patents receive to establish a comparable citation window across patents.[7] We include all citations (in patents filed in various patent offices) to the patent and its equivalents within the patent family (patent documents that share the priority date). Citations are calculated on the PATSTAT database (release April 2012), which contains citation information for

[5] For granted patents applied in 1996, the average granting decision took 5.25 years, with 25% of grants having a granting lag of seven years and longer (source: own calculations). We used patent data from the PATSTAT database downloaded in 2008.

[6] The EPO guidelines states that European patent applications are published 18 months after filing with the EPO or 18 months after priority date. However, the reality is somewhat different. Based on own calculations on all EPO applications filed in the period 1990-2005, we found that the average publication lag of EPO patent applications varies between two and three years. This is also related to the increasing popularity of PCT filings, which introduces an additional time lag between application and publication.

[7] Dropping years 2002 or 2003 to reduce truncation did not materially affect the empirical results.

patents from all the major patent offices in the world (EPO, USPTO, JPO) and a large set of national patent offices.

We also make a distinction between self-citations by the focal firms and non-self-citations. Self-citations are citations in subsequent patent applications by the same focal firm and its consolidated subsidiaries. Forward self-citations have in general been found to be a better predictor of the economic value of patents at the firm level (e.g. Hall et al., 2005 and Belenzon, 2012) because this often indicates that the invention is original and valuable enough for the firm to build future technology development efforts on it, and moreover, that it is the patent owning firm that is likely to exploit the value of the patent.

We collected firm patent data at the consolidated level: i.e. all patents of the parent firm and its consolidated (majority-owned) subsidiaries are included. For this purpose, we use lists of subsidiaries included in corporate annual reports, 10-K reports filed with the SEC in the US and, for Japanese firms, information on foreign subsidiaries published by Toyo Keizai in the yearly 'Directories of Japanese Overseas Investments'. The consolidation was conducted on an annual basis (1996-2003) to take into account changes in the group structure of the firms over time. Using consolidated patent data is important in order to obtain a complete picture of the technological activities of firms since a significant proportion of firms' patents are not filed under the parent firm name. For our sample, on average 17.6% of firm patents are filed under the name of firm subsidiaries or name variants of the parent firms.

We used information on the ownership of the patents to distinguish between solitary-owned and co-owned patents. A patent is considered as co-owned when it is jointly owned with an economic actor that is not part of the consolidated focal firm (another firm, or a university). Patents that are jointly owned by firms and individual persons have been excluded since we do not know whether these individuals are employed by the focal firm or not. Patent applicant (assignee) names referring to individual persons are identified by sector allocation algorithms (source: Van Looy et al, 2006).

We defined the corporate co-owners of patents as intra-industry partners or inter-industry partners based on the main sector(s) in which the assignee firms operate. To determine the main sector(s) of firms, we identified the technology class(es) in which the firm has filed most of its patents.[8] Technology classes are linked to sectors via the concordance table developed by Schmoch et al. (2003). This concordance table relates technology fields at the IPC 4-digit level to one of 44 economic sectors (manufacturing). The economic sectors are a combination of 3-digit and some 2-digit NACE industries, with more subclasses available for high-tech industries. Our sample firms have their main activities in 33 of the 44 industries. The ten most frequently assigned sectors are: pharmaceuticals (NACE 24.4), office machinery and computers (NACE 30), basic chemicals (NACE 24.1), electronic components (NACE 32.1), signal transmission/telecommunications (NACE 32.2), special purpose machinery (NACE 29.5), energy machinery (NACE 29.1), TV and radio receivers (32.3), non-specific purpose machinery (NACE 29.2) and motor vehicles (NACE 34). The same procedure is used to identify the main sectors of partnering firms (co-assignees on co-patents) of the focal firms, using assignee name harmonizing algorithms (Van Looy et al, 2006) to identify patents belonging to the same firm in the patent database. If the focal firm and the partner firm are active in the same sector, the co-patent is defined as intra-industry; in all other cases it is defined as inter-industry. An example of an intra-industry co-patent is EP1206457 which is co-owned by Eli Lilly (focal firm) and Ligand Pharmaceuticals; both firms have pharmaceuticals as main sector. Co-patent EP0687499 is an example of an inter-industry co-patent. It is co-owned by BASF (focal firm) and Daimler Chrysler, which have, respectively, “basic chemicals” and “motor vehicles” as main industry.

**Empirical Methods**

Following the insights from the interviews on the implications of co-patenting for value creation and appropriation, we conduct two types of analyses. First, we explore whether an (imperfect) indicator of patent value (forward citations received) differs systematically between the three types of co-

[8] In case a firm has more than one top patenting class (same number of patents), it is assigned to multiple sectors. This is the case for about 8% of our observations (firm-year observations).

patents and single firm-owned patents. In this analysis, we examine the characteristics of the firm's patent grants, including their co-patent status, applied for between 1996 and 2003. Together the 164 firms account for 85.706 patents applications during the observed time period that were subsequently granted. The empirical model at the patent level has the number of forward citations as dependent variable. Given that this dependent variable is a count measure, we apply a Poisson regression with robust standard errors to analyse the relationship between forward citations and whether or not the patent is co-owned. We differentiate the dependent variable between self-citations and non-self-citations received. We interpret the results of these analyses as partial correlations between co-ownership and citations and note an important caveat. Since co-patent status combines information on R&D collaboration and the IP sharing arrangement of this collaboration, our models do not allow to partial out the implications of IP sharing as such. In order to examine this more precisely, we would need to identify patents that are the results of collaborative R&D but owned by a single firm – information that is not available.

The second empirical model examines the impact of co-patenting activities of firms on a forward-looking measure of financial performance, Tobin's q, during 1996-2003. We adopt a dynamic growth specification, relating the proportional increase in Tobin's q to the lagged value of q, measures of (co-)patenting activities, and a set of control variables. The growth (difference) specification controls for unobserved firm features affecting market valuation levels. The inclusion of the lagged value of q also allows for the possibility of a gradual convergence in market valuation, as leading firms may be less able to record further market value growth and also controls for unobservable factors driving market value growth. The key independent variables measure new information during the year that reaches investors and affects their assessment of the future income streams of the firm. In this regard the time lag with which information reaches investors is of crucial importance. We classify patent grants at the year of application (the year the collaborative R&D was conducted). However, EPO patent applications generally take a minimum of 1,5 years and usually 2-3 years before they are published by the patent office and become fully visible to investors. On the other hand, the publication date is not always representative of the timing of patent disclosure, as firms may disclose their patent filings earlier to investors. Generally we may expect though that patents filed in year t, are most likely to affect market valuations in t+2 or t+3. Our approach in this has been to first explore the precise time lag between patent filings and market valuation effects empirically. Estimating models with various time lags, we indeed confirmed significant relationships between (co)patent applications with 2 and 3 year lags, but not for contemporaneous or 1 year lagged measures. We present the results of models with a 2 year lag, as adding additional lags reduces the number of year observations for the firms in the dataset.[9]

The phenomenon of 'delayed' effects of patent applications and evidence of co-patenting activities on market valuation help us to alleviate important concerns of an endogeneity bias. Since co-patent strategies are measured (t-2) before we measure firm's market valuation (Tobin's q, t-1) and the growth of this valuation (t), it is less likely that estimated effects of co-patenting on firm performance are biased because of unobserved firm heterogeneity (captured to an important extent by investor's valuation of the firm in t-1) and reverse causality from firm performance to co-patenting strategies (given the time ordering and the fact that the analysis controls for prior firm performance). We examined the potential presence of endogeneity more formally by means of an instrumental variable analysis. We employed a Wu-Hausman test (Wooldridge, 2001), which compares the coefficient estimates of the OLS estimates with the estimates of a model in which the potentially endogenous variables are instrumented. As instruments we calculated the intensities of co-patenting (with different types of partners: universities, intra-industry or inter-industry) at the level of technology fields (120 IPC 3-digit classes) and countries over time. The different legal and institutional environments in countries in Europe, Japan and the US, and the different technological opportunities and characteristics, are likely to lead to different co-patent strategies. Adoption of such co-patenting strategies by the focal firms is likely to be strongly associated with technology and

[9] Results of the models with other lags are available upon request. We did not uncover similar lag structures for the patent citation measures and for the (very stable) technology diversification variable, and include contemporaneous measures for these variables.

country specific practices, but is less likely to be correlated with firm-specific differences in market valuation growth. The technology and country specific co-patenting intensities are defined as the worldwide share of inter-industry, intra-industry and university co-patenting by firm applicants in the total number of patents applied for by firms – with the co-patents of the focal firm deducted.[10] In order to test for overidentification we add the size of the firm (sales) as an additional fourth instrument.

We first conducted an under-identification test to examine whether the instruments are relevant: sufficiently correlated with the endogenous regressors. The first stage regressions showed partial R-squares ranging from 6,5 to 12 percent with F values substantially above the cutoff point of 10 (ranging between 16 and 32). The instruments had a clear discriminatory effect, with intra(inter)industry co-patenting affecting only the focal firms intra(inter)industry co-patenting strategy, and university co-patenting affecting focal firms' university co-patenting strategy. The Anderson LM statistic reported a value of 57.9 rejecting underidentification with a corresponding p value <0.001. The Sargan Chi-square test for over-identifying restrictions took the value 0.06, and was insignificant with a p-value > 0.79, suggesting that our set of instruments was exogenous and valid. Finally, the Wu-Hausman test did not reject the null hypothesis that the ordinary least squared estimates of the original market value growth model are identical to the estimates of the model with instrumented variables (a value for the F statistic of 0.330 and a p-value >0.80). These results provide more confidence that the two year lagged co-patenting strategies can be regarded as weakly exogenous such that the OLS estimations are consistent.

Finally, we again note that co-patenting intensities combine information on collaboration strategies (with potential value creation) with IP sharing arrangements. We cannot directly compare co-patenting strategies with the effect of collaboration strategies without such IP sharing - as we cannot identify which patents were due to collaborative R&D but led to exclusive IP arrangements with sole owned patents for the partners. We expect that the effects of co-patenting in the market

[10] Firm and year level instruments take average values of the worldwide co-patenting intensities for the technology fields in which firms have applied for patents (weighted average based on patent shares).

value analysis are most reflective of appropriation issues as perceived by the market, as at least part of the potential positive performance effects of collaboration *per se* is already reflected in higher patent value (citations and self-citations) and a higher incidence of patenting, for which the analysis controls. Second, if there is a bias in the coefficients on co-patenting to the extent that these reflect the benefits of collaboration rather than the effects of IP sharing, we note that such bias is most likely to be positive. We estimate the market valuation growth model with ordinary least squares with cluster-robust error terms. The dataset contains 997 observations on 164 firms.

**Variables**

To examine partial correlations between patent citations and co-patenting, we conduct multivariate (robust Poisson) analyses of the number of patent citations at the patent level. The explanatory variables of interest are dummy variables indicating whether the patent is a co-owned patent with an *intra-industry, inter-industry or university partner*. The analysis includes a full set of 3-digit *IPC technology field* dummies (a patent can be assigned to multiple IPCs and hence may have multiple dummies with value 1), *year of application* dummies, and *parent firm* dummies. In addition, we include a set of other characteristics examined in prior work on patent citations: the number of *technology fields* in which the patent is classified, the number of *non-patent citations* (including citations to the scientific literature), the number of *backward citations* and the *number of inventors* listed on the patent. The number of technology fields is the number of 3 digit International Patent Classification (IPC) codes listed on the patent. A broader technological patent scope could determine the extent of patent protection and monopoly power and thus the economic value of an invention (Scotchmer, 1991). More IPC classes covered by the patent could also affect the likelihood of being cited as the patent covers more technology space. The number of non-patent citations (references primarily to scientific literature) may be associated with a higher number of received citations because the act of publication allows the ideas underlying the patent to diffuse more broadly and rapidly (Fleming and Sorenson, 2004) or because of possible greater importance of these patents

(Harhoff et al., 2003). Similarly, we control for the number of backward patent references to control for unobserved factors affecting citation behaviour (Reitzig, 2004). Finally, we include the number of inventors listed on the patent as an additional control because more inventors might lead to a faster and greater diffusion of the tacit and complex knowledge underlying the patent, resulting in different forward citation patterns. This measure is also used to control for the resources invested in developing the technology and is therefore also correlated with the number of organizations involved in the development of the technology (i.e. co-patenting).

The dependent variable in the financial performance analysis, the proportional (dlog) growth in Tobin's Q, is the growth in the ratio of the market value of a firm and the replacement (book) value of the firm's assets. A firm's market value is defined as the sum of market capitalization (share price multiplied by the number of common shares outstanding at the end of the year), preferred stock, minority interests, and total debt minus cash. In contrast to current profit indicators (e.g. sales, net profits, ROA), Tobin's Q is a forward-looking indicator that contains the stock market's assessment of firms' future financial results from current technological activities. This forward-looking aspect is important since returns from technological activities often only become manifest several years after the activities have taken place (Czarnitzki, Hall and Oriani, 2006). Information on the market and book value of firms is collected from financial databases (Worldscope and Compustat) and firms' annual reports. The key explanatory variables of interest are variables reflecting the intensity of co-patenting activities with different partners. We include three indicators of co-patenting activities representing the degree to which the firm is engaged in co-patenting activities with intra-industry, inter-industry and university partners. Each of these variables measures the share in firms' total granted patent applications of that particular co-patenting activity, with a two year lag.

As control variables we include four indicators for the firm's technological activities: R&D intensity (*R&D/assets*), patent propensity (*patents/R&D,* with a 2-year lag; R&D in million Euros), patent citations (*citations/patents, number of citations per 100 patents*), and the ratio of self-citations to total patent citations *(self-citations/citations)*. Firms that spend more money on technological activities (R&D intensity) and are more successful in these activities (patent yield) are expected to realize greater future income streams and a higher market valuation. The number of citations received is correlated with the (commercial and technical) value of the firms' patents, whereas self-citations may indicate that the patents are a source of future development and exploitation by the firm. The latter assertions have been confirmed by prior studies relating the stock market value of firms to measures of the size of their technological activities (Griliches, 1981; Pakes, 1985; Blundell et al, 1999; Hall et al, 2005). Second, we control for technology diversification by including the number of 3-digit technology classes in which the firm is active (*technology diversification,* divided by 100*)*. Third, we include a set 17 NACE 2-digit dummy variables to control for industry differences. Firms belonging to different sectors face different competitive pressures and opportunities, which may translate into performance differences. Fourth, we include home *country* (US, Japan, and 11 European countries) and *year* (1996-2003) dummies to control for differences in macro-economic trends across time and countries that may impact the stock market valuation of firms. Finally, we include the one-year lagged value of Tobin's Q to account for dynamic patterns in market valuation growth and to control for unobserved firm heterogeneity.

## EMPIRICAL RESULTS

Table 1 shows the pattern of co-patenting activities by the firms in our sample during 1995-2003. The number of granted patent applications hovers around 10.000-11.000 and starts to decline from 2001, due to the truncation effect of grant lags. The truncation appears somewhat stronger for inter-industry copatents in 2002-2003. Co-patenting with inter-industry partners is most prevalent, and makes up 1.5-2 % of the firms' patents; intra-industry co-patents account for 0.9-1.5 %. University co-patenting is rather rare, in contrast, and amounts only to 10-20 cases per year (0.1-0.2

% of total patents). The percentages show no specific trend, but rather display a relatively stable pattern of co-patenting around 3 %.[11]

INSERT TABLE 1

Table 2 present the empirical results of the negative binomial regression models of the number of citations a patent receives. Model 1 includes the dummy variables indicating whether the patent is a co-patent or not and sets of 3-digit technology field, firm, and year dummies. Model 2 adds other patent characteristics, with the exception of the number of inventors – the patent characteristic correlated with co-patent status. Model 3 also adds the latter variable. Models 4 and 5 present the comparative results of the specification of model 3 for the alternative dependent variables self-citations and non-self-citations.

INSERT TABLE 2

The empirical results reported in model 1 show that, controlling for technology field, patenting firm, and year of application, co-owned patents with partner firms (intra-industry or inter-industry) are significantly correlated with higher forward citation rates and as such signal more economical value. The coefficients imply an 11-13 % citation premium for co-patents. The coefficient for university co-patenting is relatively large, but not significantly different from zero.[12] In model 2, the additional patent characteristics, with the exception of the number of technology classes of the patent, have positive coefficients and are statistically significant, while the co-patenting coefficients remain largely unchanged. When the number of inventors is included in model 3, however, the coefficients on co-patents are sharply reduced and become insignificant, while the coefficient on the number of inventors itself is positive and highly significant. While these findings are not in contrast with the notion that IP sharing may have positive value creation effects, in general it appears difficult

[11] This percentage is below what can be observed for the EPO patent system as a whole; the difference is due to 1) the exclusion here of co-patenting with individuals 2) the exclusion of co-patenting with assignees/patent holders belonging to the same firm. While the latter are co-patents in a strict sense, they are not due to interfirm R&D collaboration and IP sharing.

[12] The non-significance of university co-patents may be partially due to the small number of observations in the sample, which renders it difficult to estimate the coefficient with precision.

to disentangle the effect of co-patenting from the number of inventors' effect, as co-patents are associated with larger inventor teams.

In models 4 and 5, the empirical results reveal some interesting contrasts. While co-patents do appear to receive more citations from other firms (12-14 %), co-patenting with other firms is associated with a significantly *smaller* number of self-citations (in the range of 32-48 %), while university co-patenting is not significantly associated with a greater or smaller incidence of self-citations and non-self-citations. The positive effect on non-self-citations may have a natural explanation: compared with focal firms' single owned patents, co-patents with other firms will increase the probability that these partner firms cite the patent in their future technology development efforts. More salient is the strongly negative effect on self-citations. This suggests that firms build less in their future R&D efforts on co-owned inventions as compared to single owned inventions. This interpretation is in line with the notion of appropriation difficulties of shared technologies, which may restrict focal firms to exploit and build on co-owned technologies. We examine the appropriation effects of co-patenting in more detail in the firm performance analysis.

**Firm Performance Analysis**

We now turn to the analysis of financial performance – market valuation growth. Of the 997 firm-year observations, co-patenting with any partner is observed in 538 cases. Table 3 shows descriptive statistics of the variables used in the analyses. The table shows a positive correlation between the share of university co-patenting and (growth in) q. The share of intra-industry co-patenting, in contrast, is negatively correlated with the level of q as well as the growth in q; for vertical co-patents a negative correlation is only observed with the level of q. Furthermore, it is striking that most technology related variables (patents/R&D, R&D/assets, citations/patents) are negatively correlated with the co-patent variables.[13] Hence, co-patenting appears associated with a poorer score on most of the firm-level measures of firm performance technological strength, suggesting that co-patenting

[13] Similar correlations are obtained when using contemporaneous measures of technological strength, tobin's q and the co-patenting variables.

may more often be a strategy chosen by firms lacking (financial) resources. Our analysis factors out this effect by controlling for these characteristics of firms and exploiting the time ordering of co-patenting strategies and their informational effect on market valuation. We return to this issue in the discussion section. Finally, lagged q and growth in q are negatively correlated, which indicates that market valuation growth is more difficult to achieve by market valuation leaders. The correlations between the other independent variables are relatively low and do not raise multicollinearity concerns.

INSER TABLE 3

Table 4 contains the results of the analysis of market valuation growth. Model 1 excludes the focal co-patenting variables and model 2 shows the results when these are added. In both models, the coefficient on the lagged dependent variable is negative, suggesting that firms leading in market valuation on average have lower valuation growth. Model 1 shows that besides past q, R&D intensity, the ratio of patents to R&D, and the citation ratio have positive and significant coefficients. In model 2, the ratio of self- citations to total citations is additionally significant (at the 10 percent level), consistent with prior research suggesting that self-citations are an important driver of firm value (e.g. Belenzon, 2012). Firms that exhibit greater technology diversification show significantly smaller growth in market valuation, which may be reflecting investors' preference for a focus on a set of core businesses and technologies.

In model 2, we observe a negative and significant coefficient for the share of co-patents with intra-industry partners. The estimated coefficient implies that a standard deviation (0.063) change in the share of co-patents with intra-industry partners reduces growth by about 2 percent points. Co-patenting with inter-industry partners has no appreciable effect on market valuation growth, while co-patenting with universities has a significantly positive effect. The estimated coefficient implies that a standard deviation change in university co-patenting enhances market value growth by roughly 3.5 percent points. This ranking of effects is fully in line with the view emerging from our interviews that IP sharing is unlikely to hamper appropriation if it concerns collaboration with universities, and more likely to affect appropriation in intra-industry partnerships than in inter-industry partnerships. In the absence of appropriation issues, collaboration with universities, as evidenced by co-patents, may hold the promise of more radical technologies for future exploitation, as suggested by prior studies on R&D collaboration and performance (e.g. Belderbos et al., 2004; Faems et al. 2005). In contrast, in the case of intra-industry co-patenting the appropriation liabilities of IP sharing are dominant and there are clear negative (expected) performance consequences of high shares of co-owned technologies in firms' patent application portfolios. For inter-industry co-patenting the liabilities of IP sharing are much less pronounced and may be neutralized by potential residual value creation effects of IP arrangements.

INSERT TABLE 4

## DISCUSSION AND CONCLUSION

Relying on both qualitative and quantitative data, this paper explores the role and performance implications of co-patents. Our findings provide a richer understanding of the challenges and opportunities that firms face when they have to make strategic decisions on IP ownership in open innovation activities such as collaborative R&D. First, we show that the value appropriation liabilities of sharing IP ownership depend on the type of partner involved. Second, we provide first indications that engaging in co-patenting arrangements with collaborative partners might trigger positive value creation effects. Below, we discuss these findings and their implications for future research on open innovation in general and co-patenting in particular.

### Value Appropriation Liabilities of Co-Patenting Activities

In line with previous research (Belderbos et al., 2010; Hagedoorn, 2003), our findings show that, in general, co-ownership of patented inventions entails important value appropriation liabilities. However, making a more fine-grained distinction between different types of partners (i.e. intra-industry, inter-industry, and universities), we observe that these negative effects are most outspoken when firms co-patent with firms that are situated within the same industry. This finding suggest that, to assess the extent to which co-patenting might restrict firms' ability to reap commercial benefits of collaborative R&D efforts, it is important to consider the extent to which partners' have overlapping exploitation domains. When both partners are active in different exploitation domains (i.e. the case of inter-industry partners), sharing ownership of knowledge that emerges out of collaborative R&D is less likely to restrict firms' ability to fully appropriate the commercial benefits of the technology at hand. In contrast, when firms are active within the same industry, there is a high likelihood that, at least for some potential application domains, shared IP is associated with competing exploitation strategies reducing the value appropriation potential for the focal firm.

At the same time, we observe a significant positive relationship between the share of co-patents with universities and market valuation growth. This result is likely to derive from the lack of appropriation liabilities due to co-patenting with this type of partner. In our interviews, it was mentioned that firms sometimes allow universities to co-patent to provide strong signals of the existence of embedded relationships between the focal firm and universities, while co-patenting does not imply that universities seek to commercialize the technologies. Hence, co-patenting should put the focal firm in a favorable position with respect to appropriating new knowledge from this particular type of partner and may generate relatively strong investor responses. In addition, previous research (e.g. Belderbos et al., 2004. Faems et al., 2005) has indicated that collaboration with universities is especially relevant for developing products or services of a more novel nature. Higher levels of novelty, combined with less 'competition' in terms of value appropriation is likely to generate the observed positive performance effects of co-patenting with universities.

Whereas these results provide valuable insights into the value appropriation consequences of co-patents, we acknowledge that additional research is necessary. Interviewees, for instance, stressed the opportunity to contractually mitigate the value appropriation risks of co-patents. In particular, they stressed that, through negotiating clear rules about the division of exploitation rights on co-owned knowledge, firms may be able to reduce the risk that co-patenting triggers competitive threats within their existing market domains.

> 'Interfirm collaboration can result in co-ownership of IP. [However], we will make sure that the exploitation rights on this co-owned IP are clearly divided among the partners.'

In other words, they suggest that partners might choose to co-own knowledge, but at the same time contractually divide the exploitation rights of such co-owned knowledge. These interview insights suggest that, to further improve our understanding of the value appropriation consequences of different collaborative IP arrangements, it is not only important to look at the type of partner involved in co-patenting activities, but also to assess how the exploitation rights on such co-owned knowledge are distributed among the involved partners. However, obtaining information on exploitation rights will remain an important challenge. In contrast to information on collaborative IP, which is publicly disclosed, contractual information on exploitation rights tends to be regarded as highly sensitive information by firms. Nevertheless, some scholars (e.g. Hagedoorn and Hesen, 2007; Elfenbein and Lerner, 2003, 2012) have already demonstrated that it is possible to construct relatively large datasets on collaborative contractual agreements. We therefore encourage future research that provides in-depth insights into the division of co-owned exploitation rights and their performance implications.

One important concern is that our findings might be driven by reverse causality: financially and technologically weaker firms are more likely to engage in co-patenting strategies. In our interviews, we identified potential explanations for such an effect. First, it was stressed that, the stronger the bargaining power of the firm within a collaborative partnership, the more likely it is able to solely own foreground IP on knowledge that is strategically important. Firms with less bargaining power, however, are more likely to be forced into a co-ownership arrangement with competitors regarding knowledge that is generated during the collaboration and that may be strategically important:

> 'In general, we try to avoid co-patents. When you are in a strong position, you can negotiate away co-patents. When you face a strong partner, you might not have the necessary power to do this.'

> 'The negotiation position influences the division of foreground IP. The stronger the bargaining position, the more likely you are able to claim sole ownership and the less likely you need to give the other partner shared ownership.'

This suggests that weaker market performance may decrease firms' bargaining power in collaborative R&D partnerships with intra-industry partners, resulting in increased shares of co-patents with intra-industry partners.

While we do find evidence that at the time of patent application financially and technologically weaker firms are more likely to co-patent, we do not believe that our results in the market value regression are driven by such reverse causality. Important timing effects embedded in the patenting process make it unlikely that firm performance drives the negative effect of co-patenting with intra-industry partners. First, growth in Tobin's q is driven by information available to investors at the time. As argued before, patent applications become public only with a lag of 2 to 3 years. As a result, the weak firm performance that possibly determines the firm's co-patenting behavior took place 3 to 4 years before the time when we determine the effect on market valuation. In addition, we do control for firm performance in the previous year which should capture any of the more persistent unobserved effects possibly driving both co-patent share and market value. Finally, there is little reason why only intra-industry co-patenting would display this reverse causality effect and not co-patenting with other partner types.

A second important concern relates to the fact that we do not observe the potential ex ante agreements between partners. If appropriation concerns are important, one might expect that we only observe co-patenting between partners that have resolved these issues through additional contractual terms or found a way to circumvent co-patenting. Obviously, if such selection had taken place we would not observe a negative effect of intra-industry co-patenting. Our empirical results do beg the question why firms engage in agreements that over time reduce their market value compared to sole ownership of the technology. The explanation is that the firm must be facing severe constraints in technology development efforts. The reason why they partner in the first place is that they need access to the partner's technological knowledge. Sole ownership might not be feasible as the partner might be unwilling to relinquish control and partners are forced to co-own the technology. Collaboration and IP sharing may be the only route to successful invention and patent grants. So while we do find a robust negative effect on growth in market value of intra-industry co-patenting, firms may not readily have the option to move to sole ownership of the technology.

**Value Creation Opportunities of Co-Patenting Arrangements**

Research on the governance of technology alliances has provided evidence that the initial contractual design of technology partnerships can have important value creation implications. Several scholars (e.g. Anderson and Dekker, 2005; Sampson, 2004), for instance, show that misalignment between transactional characteristics and contract complexity might substantially hamper partners' ability to generate value within alliances. Making a conceptual distinction between narrow and broad contractual interface structures, Faems et al. (2008) also demonstrate that the content of the contract can have important implications in terms of sense making and trust building processes between partners in R&D alliances, which subsequently influence partners' ability to jointly solve unexpected technological problems.

Focusing on the particular issue of contractual IP arrangements, our interviewees suggested that ex-ante negotiation of co-patenting procedures might have positive value creation implications as it (i) reduces ex-ante knowledge appropriation concerns for knowledge domains that do not clearly belong to one of the involved partners and (ii) fosters positive goodwill trust dynamics. Moreover, our empirical data provide some preliminary indications for the presence of such value creation effects. Using forward citations as an indicator of technological performance, we observed that co-patents with inter-firm and intra-firm industry partners receive more citations than single-owned patents, with the caveat that we could not disentangle this from the positive effect of larger inventor teams as such. At the same time, self-citations are negatively correlated with co-patenting - consistent with the appropriation challenges discussed above. This indicates that firms are less likely to further develop co-owned technology internally, although such consecutive developments are often crucial for firms to appropriate economical returns to their innovation efforts as demonstrated by Hall et al. (2005) and more recently by Belenzon (2012). Whether this is inspired by opportunity cost considerations (which might favor fully owned developments) or difficulties, restrictions on further development related to the IP sharing arrangement, or difficulties in terms of mobilizing required capabilities (including partners) remains to be further investigated.

We acknowledge that our findings have to be interpreted with caution. In our study we were only able to observe the likely output of co-patenting arrangements (i.e. co-patent application) and not the presence of ex-ante co-patenting arrangements itself. We therefore point to the relevance and importance of future research that allows studying the presence and nature of contracts jointly with the absence or presence of co-patenting arrangements and their value creation consequences. Given our focus on large R&D intensive firms with relatively large patent portfolio, our findings are furthermore not representative for the specific challenges facing small firms contemplating R&D collaboration and sharing of IP culminating in co-patent activities. We suggest that future research efforts focus on examining co-patenting in smaller firms specifically. Finally, the different legal framework and institutions relevant to EPO and USPTO patents, with their differential consequences for IP sharing, is a source of variation that could be exploited in future research comparing firms' strategies in the two patent jurisdictions.

## Conclusion

Engaging in open innovation efforts does not only trigger value creation opportunities, but also entails substantial value appropriation challenges. In this paper, we explored the role of joint patent ownership in addressing this 'openness paradox.' We believe that our findings will inspire academic scholars to further examine the value appropriation liabilities as well as value creation opportunities of co-patenting and collaboration arrangements. In addition, we believe that our insights will help practitioners in further optimizing their collaborative IP strategies with different types of partners.

## REFERENCES


AIPPI. 2007. Summary Report Question Q194. The Impact of Co–Ownership of Intellectual Property Rights on their Exploitation.

Albert, M.B., D. Avery, F. Narin, and P. McAllister, "Direct validation of citation counts as indicators of industrially important patents," *Research Policy* 20 (1991), 251-259.

Appio, Landoni and Van Looy, 2012. Exploring indicators of Open Innovation: the role of co-patents. Paper presented at the STI Conference Leiden, 2010. KU Leuven - MSI Working Paper, 2012.

Arundel, A. and Kabla I. (1998). What percentage of innovations are patented? Empirical estimates from European firms. Research Policy, 27, 127-141.

Basberg B. (1987). Patents and the measurement of technological change: A survey of the literature. Research Policy, 16, 131-141.

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. Research Policy 33, 1477-1492.

Belderbos, R., Faems, D., Leten, B., Van Looy, B., 2010. Technological Activities and Their Impact on the Financial Performance of the Firm: Exploitation and Exploration within and between Firms. J. Prod. Innovation Manage. 27, 869-882.

Belenzon S. (2012) Cumulative innovation and market value: evidence from patent citations, The Economic Journal, 122 (March), 265–285.

Blundell, R., Griffith, R., and van Reenen, J. (1999). Market Share, Market Value, and Innovation in a Panel of British Manufacturing Firms. Review of Economic Studies 66:529–554.

Carlson, D., Barney, J.R., 1999. The division of rights among joint inventors: Public policy concerns after ehticon versus surgical. The Journal of Law and Technology 39, 251.

Carson, S.J., Madhok, A., Varman, R., John, G., 2003. Information processing moderators of the effectiveness of trust-based governance in interfirm R&D collaboration. Organization Science 14, 45-56.

Cassiman, B. 2008. "Research Joint Ventures," in the New Palgrave Dictionary of Economics, second edition.

Cassiman, B., Veugelers, R., 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. Management Science 52, 68-82.

Chesbrough, H., 2003. The era of open innovation. Mit Sloan Management Review 44, 35-41.

Chesbrough, H., 2006. Open Innovation: A new paradigm for understanding industrial innovation, in

Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford, pp. 1-12.

Chesbrough, H., Rosenbloom, R., 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Industrial and Corporate Change 11, 529-555.

Czarnitzki, D., Hall, B.H., and Oriani, R. (2006). The Market Valuation of Knowledge Assets in US and European Firms. In: The Management of Intellectual Property, ed. D. Bosworth, and R. Webster. Cheltenham, UK: Edward Elgar, 111–131.

Doz, Y., Hamel, G., 1997. , in Tushman, M.L., Anderson, P. (Eds.), The use of Alliances in Implementing Technology Strategies; Managing Strategic Innovation and Change: A Collection of Readings. Oxford University Press, NY, pp. 556-580.

Doz, Y.L., 1996. The evolution of cooperation in strategic alliances: initial conditions or learning processes? Strategic Manage. J. 17, 55-83.

Dyer, J.H., Singh, H., 1998. The relational view: cooperative strategy and sources of interorganizational competitive advantage. Academy of Management Review 23, 660-679.

Faems, D., Van Looy, B., Debackere, K., 2005. Interorganizational collaboration and innovation: Toward a portfolio approach. J. Prod. Innovation Manage. 22, 238-250.

Faems, D., Janssens, M., Madhok, A., Van Looy, B., 2008. Toward an Integrative Perspective on Alliance Governance: Connecting Contract Design, Trust Dynamics, and Contract Application. Academy of Management Journal 51, 1053-1078.

Faems, D., Janssens, M., van Looy, B., 2007. The initiation and evolution of interfirm knowledge transfer in R&D relationships. Organ. Stud. 28, 1699-1728.

Fleming, L., O. Sorenson. (2004). Science as a map in technological search. Strategic Management Journal. 25 909-928.

Gnyawali, D. R., & Park, B. (. (2011). 'Co-opetition between giants: Collaboration with competitors for technological innovation'. Research Policy, 40, 650-63.

Gnyawali, D. R., & Park, B. (. (2009). 'Co-opetition and technological innovation in small and medium-sized enterprises: A multilevel conceptual model'. Journal of Small Business Management, 47, 308-30.

Gambardella, A., Harhoff, D., and Verspagen, B. (2008). The Value of European Patents. CEPR discussion paper no. 6848.

Griliches, Z. (1981). Market Value, R&D and Patents. Economic Letters 7:183–187.

Griliches, Z. (1990). Patent Statistics as Economic Indicators: A Survey. Journal of Economic Literature 28(4):1661–1707.

Hagedoorn, J., 2003. Sharing intellectual property rights - an exploratory study of joint patenting amongst companies. Industrial and Corporate Change 12, 1035-1050.

Hagedoorn, J., Van Kranenburg, H., Osborn, R.N., 2003. Joint patenting amongst companies: Exploring the effects of inter-firm R&D partnering and experience. Managerial and Decision Economics 24, 71-84.

Hall, B., Jaffe, A., and Trajtenberg, M. (2005). Market Value and Patent Citations. Rand Journal of Economics 36(1):16–38.

Harhoff, D., F. Narin, F.M. Scherer, and K. Vopel, "Citation Frequency and the Value of Patented Innovation," *Review of Economics and Statistics* 81:3 (1999), 511-515.

Harhoff, D., F. Scherer, K. Vopel. (2003). Citations, Family Size, Opposition and the Value of Patent Rights - Evidence from Germany. *Research Policy*. 32(8) 1343-1363.

Henderson, R., A.B. Jaffe, and M. Trajtenberg, „Universities as a source of commercial technology: A detailed analysis of university patenting, 1965-1988," *The Review of Economics and Statistics* (1998), 119-127.

Heiman, B.A., Nickerson, J.A., 2004. Empirical evidence regarding the tension between knowledge sharing and knowledge expropriation in collaborations. Manage. Decis. Econ. 25.

Henkel, J., 2006. Selective revealing in open innovation processes: The case of embedded Linux. Research Policy 35, 953-969.

Jaffe, A. and Lerner, J. (2004). Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do about It. Princeton, NJ: Princeton University Press.

Jaffe, A.B., M. Trajtenberg, and M. Fogarty, „Knowledge spillovers and patent citations: Evidence from a survey of inventors," *American Economic Review* 90:2 (2000), 215-218.

Laursen, K., Salter, A., 2006. Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. Strategic Manage. J. 27, 113-150.

Laursen, K., Salter, A., 2005. The paradox of openness of knowledge for innovation.

Levin, R., Klevorick, A., Nelson, R., and Winter, S. (1987). Appropriating the Returns from Industrial Research and Development. Brookings Papers on Economic Activity 3:783–831.

Mansfield, E. (1986). Patents and Innovation: An Empirical Study. Management Science 32(2):173–181.

Madhok, A., Tallman, S.B., 1998. Resources, transactions and rents: managing value through interfirm collaborative relationships. Organization Science 9, 326-339.

Merges, R.P., Locke, L.A., 1990. Co-ownership of patents: A comparative and economic view. Journal of the Patent and Trademark Office Society 72.

Pakes, A. 1995. On Patents, R&D, and the Stock Market Rate of Return, Journal of Political Economy, University of Chicago Press, vol. 93(2), 390-409.

Paradiso, R.J., Pietrowski, E., 2009. Dilemmas of joint patent ownership. New Jersey Law Journal 197, 912-913.

Pavitt, K. (1985). Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems. Scientometrics 7(1):77–99.

Quillen, C. and Webster, O. (2001). Continuing Patent Applications and Performance of the US Patent Office. Federal Circuit Bar Journal 11(1):1–21.

Reitzig, M. (2004). Improving patent valuations for management purposes —validating new indicators by analyzing application rationales. Research Policy. 33 939–957.

Ritala, P., & Hurmelinna-Laukkanen, P. (2009). 'What's in it for me? Creating and appropriating value in innovation-related coopetition'. Technovation, 29, 819-28.

Schankerman, M., and A. Pakes, "Estimates of the value of patent rights in European countries during the post-1950 period," *The Economic Journal* 96 (1986), 1052-1076.

Scotchmer, S. (1991). Standing on the shoulders of giants: Cumulative research and the patent law. The Journal of economic Perspectives. 5(1) 29-41.

Schmoch, U., Laville, F., Patel, P., & Frietsch, R. (2003). Linking Technology Areas to Industrial Sectors: Final Report to the European Commission , DG Research.

Trajtenberg, M., "A Penny for your quotes: Patent citations and the value of innovations," *RAND Journal of Economics* 21:1 (1990): 172-187.

Vanhaverbeke, W., 2006. The interorganizational context of open innovation, in Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm, pp. 205-219.

Van Looy, B., Du Plessis, M. and Magerman, T. (2006). *Data production methods for harmonized patent indicators: assignee sector allocation*. EUROSTAT Working Paper and Studies, Luxemburg.

Van Pottelsberghe de la Potterie, B. and François, D. (2006). The Cost Factor in Patent Systems. EPO working paper CEB 06-002.

Veugelers, R. and B. Cassiman. (2005). R&D Cooperation between Firms and Universities: Some empirical evidence from Belgium, The International Journal of Industrial Organization, 23 (5-6), p. 355-379.

West, J. (2006) "Does Appropriability Enable or Retard Open Innovation?" in Henry Chesbrough, Wim Vanhaverbeke and Joel West, eds., *Open Innovation: Researching a New Paradigm,* Oxford: Oxford University Press, 2006, pp. 109-133.

**Table 1. Trends in co-patenting activity (164 sample firms)**

| **year** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
|---|---|---|---|---|---|---|---|---|---|
| copatents - interindustry | 166 | 207 | 189 | 209 | 176 | 188 | 147 | 79 | 49 |
| *% total* | *1.6* | *2.0* | *1.7* | *2.0* | *1.6* | *1.9* | *1.7* | *1.2* | *1.1* |
| copatents - intraindustry | 120 | 98 | 118 | 105 | 122 | 138 | 103 | 69 | 52 |
| *% total* | *1.2* | *0.9* | *1.1* | *1.0* | *1.1* | *1.4* | *1.2* | *1.1* | *1.1* |
| copatents - universities | 15 | 20 | 16 | 16 | 11 | 21 | 9 | 4 | 7 |
| *% total* | *0.15* | *0.19* | *0.15* | *0.15* | *0.10* | *0.21* | *0.10* | *0.06* | *0.15* |
| all patent grants | 10112 | 10424 | 10804 | 10607 | 10707 | 10043 | 8862 | 6543 | 4619 |

**Table 2. Robust Poisson Regression of Forward Citations Received (patent level)**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| | *all cites* | *all cites* | *all cites* | *selfcites* | *nonselfcites* |
| copatent - interindustry | 0.114** | 0.119*** | 0.025 | -0.488*** | 0.142*** |
| | [0.046] | [0.046] | [0.046] | [0.052] | [0.051] |
| copatent - intraindustry | 0.130*** | 0.129*** | 0.021 | -0.322*** | 0.118*** |
| | [0.043] | [0.043] | [0.043] | [0.073] | [0.045] |
| copatent - universities | 0.213 | 0.179 | 0.084 | -0.151 | 0.159 |
| | [0.163] | [0.164] | [0.165] | [0.178] | [0.183] |
| backward patent citations | | 0.021*** | 0.019*** | 0.019*** | 0.019*** |
| | | [0.002] | [0.002] | [0.002] | [0.002] |
| non-patent citations | | 0.038*** | 0.037*** | 0.024*** | 0.042*** |
| | | [0.005] | [0.005] | [0.005] | [0.005] |
| number of technology fields | | 0.066 | 0.055 | 0.093 | 0.046 |
| | | [0.107] | [0.107] | [0.166] | [0.118] |
| number of inventors | | | 0.058*** | 0.088*** | 0.047*** |
| | | | [0.003] | [0.003] | [0.003] |
| 3-digit IPC dummies | Included | Included | Included | Included | Included |
| firm dummies | Included | Included | Included | Included | Included |
| year dummies | Included | Included | Included | Included | Included |
| Observations | 85706 | 85706 | 85706 | 85706 | 85706 |
| Loglikelihood | -461334 | -464959 | -467367 | -183918 | -404446 |
| Pseudo R2 | 0.129 | 0.133 | 0.14 | 0.115 | 0.151 |

* significant at 10%; ** significant at 5%; *** significant at 1%, robust standard errors in parentheses

**Table 3. Market valuation growth model: means, standard deviations and correlations**

| | | mean | st dev | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | growth (dln) Tobin's q | -0.018 | 0.401 | | | | | | | | | |
| 2 | lagged Tobin's q | 0.275 | 0.776 | -0.251 | | | | | | | | |
| 3 | intraindustry copatenting | 0.022 | 0.064 | -0.042 | -0.078 | | | | | | | |
| 4 | interindustry copatenting | 0.025 | 0.064 | 0.023 | -0.139 | 0.054 | | | | | | |
| 5 | university copatenting | 0.003 | 0.017 | 0.042 | 0.121 | 0.007 | 0.03 | | | | | |
| 6 | patents/RD | 0.154 | 0.167 | 0.063 | -0.089 | -0.053 | -0.059 | -0.079 | | | | |
| 7 | R&D/assets | 0.063 | 0.048 | -0.007 | 0.490 | -0.043 | -0.122 | 0.063 | -0.284 | | | |
| 8 | citations/patents | 0.067 | 0.045 | 0.023 | 0.381 | -0.083 | -0.067 | 0.034 | -0.189 | 0.395 | | |
| 9 | selfcitations/citations | 0.223 | 0.153 | 0.027 | 0.064 | 0.068 | -0.040 | 0.021 | 0.092 | -0.003 | -0.025 | |
| 10 | technology diversification | 0.661 | 0.545 | 0.018 | -0.344 | -0.072 | 0.029 | -0.064 | 0.23 | -0.192 | -0.165 | -0.011 |

N=997

**Table 4. The effect of Copatenting on the Growth in Market valuation (Tobin's q)**

| | Model 1 | Model 2 |
|---|---|---|
| intraindustry copatenting t-2 | | -0.360*** |
| | | [0.132] |
| interindustry copatenting t-2 | | -0.018 |
| | | [0.140] |
| university copatenting t-2 | | 1.591*** |
| | | [0.476] |
| lagged Tobin's q | -0.182*** | -0.188*** |
| | [0.019] | [0.019] |
| R&D/assets | 0.912** | 0.954*** |
| | [0.366] | [0.347] |
| patents/RD t-2 | 0.260*** | 0.254*** |
| | [0.085] | [0.084] |
| citations/patents | 0.947** | 0.916** |
| | [0.428] | [0.428] |
| selfcitations/citations | 0.106 | 0.124* |
| | [0.071] | [0.070] |
| techology diversification | -0.050*** | -0.054*** |
| | [0.018] | [0.019] |
| country dummies | included | included |
| year dummies | included | included |
| 16 sector dummies | included | included |
| | | |
| Observations (firms) | 997 | 997 |
| R squared | 0.317 | 0.324 |
| Loglikelihood | -312.3 | -306.8 |

* significant at 10%; ** significant at 5%; *** significant at 1%
firm-clustered standard errors in parentheses