IPCR 14-12-10

THE ALLOCATION OF INTELLECTUAL PROPERTY CONTROL RIGHTS IN R&D ALLIANCES

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We thank Hans Frankort, Carolin Haeussler, Matt Higgins, Aija Leiponen, Ammon Salter, and participants at seminars at Grenoble Graduate School of Business, Imperial College London, Maastricht University, and the Society for Empirical Legal Studies 2010 annual conference at Yale University for helpful suggestions and comments on earlier versions of this paper.

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Abstract

We study control rights, i.e. contractual obligations regarding ownership and decision making, allocated to R&D alliance contract partners in the biopharmaceutical industry. More in particular, we focus on the allocation of intellectual property control rights as seen from the perspective of the firm that is the main source of the technology that is developed or used within the alliance. Extending previous research, our empirical analysis of a sample of about 300 R&D alliance contracts considers three main conditions that are expected to affect the allocation of control rights. Our findings indicate that conditions such as inter-firm asymmetries in innovative capabilities, the breadth of the technology scope of alliances, and the exclusivity in R&D alliance partnering, that limits the options for firms to engage in related alternative R&D activities with third parties, do indeed play a decisive role in the allocation of intellectual property control rights to the principal technology supplying partner. (Word count: 151)

INTRODUCTION

In recent years we notice a gradual increase in the number of empirical studies on contract design, including studies with a focus on inter-firm alliances and the allocation of control rights to alliance partners. These control rights refer to provisions in alliance contracts that give a contract party, i.e. an alliance partner, certain rights with regard to ownership and decision making. In the current contribution we study control rights allocated to partners within R&D alliances formed in the biopharmaceutical industry. Control rights are critical to any sort of inter-firm alliance but, compared to other alliances, for instance manufacturing or marketing alliances, even more so in case of R&D alliances. In particular with R&D alliances it is difficult for firms to ex ante calculate future innovation rents created by their joint R&D and to decide about the actual distribution of these rents among partners. Hence, we can expect that the allocation of control rights plays an important role in the negotiation of alliances and the design of alliance contracts (see also Lerner & Merges, 1998).

Although our study, as elaborated upon below, shares a number of insights with previous studies, it differs from the existing body of empirical literature with respect to a number of crucial elements. Most previous studies (Adegbesan & Higgins, 2009; Haeussler & Higgins, 2009; Higgins, 2007; Lerner & Merges, 1998; Lerner, Shane & Tsai, 2003) focus on a typical 'large pharma - small biotech' alliance setting. The current paper covers a wider range of collaborative R&D efforts, with various combinations of different categories of firms, such as small, medium-size and larger biotech firms, medium-size and large pharmaceutical firms, and large diversified chemical firms. This setting is more in line with both the market structure and the pattern in R&D alliances in the biopharmaceutical industry as found at the turn of the century. During this more recent period, the focus in alliance formation has shifted from an almost exclusive large pharma – small biotech setting to a less

uneven distribution where alliances between various ‘size’ groups are found to be relevant (Roijakkers & Hagedoorn, 2006).

Also, in the previously mentioned contributions, the allocation of control rights is studied from the perspective of either the small biotech firm or the large pharmaceutical firm. In the current analysis, given its broader perspective, the allocation of control rights is viewed from the perspective of the firm that is the main source of the technology that is developed further or used within the alliance. We label that firm as the principal technology supplying partner. For firms in an alliance, but most certainly for the principal technology supplying partner, control over the outcome of this joint R&D is crucial for the appropriation of future innovation rents. In particular for the principal technology supplying partner of an R&D alliance, one can expect that, given its critical technological input, it is vital to negotiate a range of intellectual property control rights for its R&D alliance contract as a claim on future innovation rents.

Finally, although previous work has taken a look at intellectual property as a sub-category of control rights, the main focus of these studies is on the allocation of control rights in general. These more general control rights refer to the combined management, governance, planning, and property aspects of alliances (Adegbesan & Higgins, 2009; Higgins, 2007; Lerner & Merges, 1998). In the following, we study the allocation of intellectual property control rights as a specific category of control rights *sui generis*. Given the nature of R&D alliances where firms jointly perform R&D or R&D is shared between partners, intellectual property control rights are a crucial element in the contract design for this specific group of alliances (Hagedoorn & Hesen, 2007). As such, compared to previous contributions, our study takes a closer and more focused look at the determinants of intellectual property control rights in R&D alliance contracts.

Although our paper diverts from other studies along the lines depicted in the above, it also elaborates on a number of interesting directions for empirical research as suggested by the current literature on contract design. In line with these directions, we will concentrate our analysis on three main conditions that are expected to affect the allocation of control rights: i.e. an inter-partner condition, an alliance scope condition, and a competitive condition.

The first condition that we refer to in our study considers inter-partner differences through the impact of inter-firm asymmetries within alliances (Adegbesan & Higgins, 2009; Aghion & Tirole, 1994; Lerner & Merges, 1998). In that context we focus on R&D alliance partners' asymmetries in innovative capabilities. The second condition deals with the alliance scope in terms of both the alliance focus on different stages of the innovation process (Adegbesan & Higgins, 2009; Haeussler & Higgins, 2009; Higgins, 2007; Lerner, Shane & Tsai, 2003) and the breadth of an alliance as indicated by the number of technology applications (Hansen & Higgins, 2008). The third condition, i.e. the competitive condition, refers to the exclusivity of contracts that limits the options for firms to engage in related alternative activities with third parties (Elfenbein & Lerner, 2009). While our contribution reveals some interesting counter-intuitive empirical results, our main findings do indicate that conditions that refer to inter-firm asymmetries, in particular asymmetries in innovative capabilities, the technological breadth of alliances, and the exclusivity in alliance partnering play a decisive role in the allocation of intellectual property control rights to principal technology supplying alliance partners.

THEORY DEVELOPMENT AND HYPOTHESES

Inspired by the Aghion & Tirole (1994) qualification of the classical Grossman-Hart-Moore (GHM) property rights theorem (Grossman & Hart, 1986; Hart & Moore, 1990), we take the relative bargaining power of partners as an important condition for the allocation of control

rights (Adegbesan & Higgins, 2009). In the context of an R&D alliance, the technological strength of the principal technology supplying partner, reflecting its long-term innovative capabilities, can be seen as an important element of the bargaining power of that firm vis-à-vis its partner. As the technology of the principal technology supplying partner is the main source of the technology used or developed further through the alliance, we expect that the higher the technological strength of the principal technology supplying partner, based on its long-term innovative capabilities, the more instrumental that firm is to the success of the alliance. Moreover, the higher the technological strength of the principal technology supplying firm vis-à-vis its partner, the more crucial its role in the R&D alliance. As such the bargaining power of the principal technology supplying firm in terms of its technological strength is expected to condition the allocation of intellectual property control rights to that firm.

However, the technological strength of a firm is also attractive to its (potential) partner because the higher its technological strength, the stronger its long-term innovative capabilities, the more the firm becomes an interesting R&D alliance partner. As stated by Baum, Calabrese & Silverman (2000), a technologically skilled and innovative firm is a very attractive partner as cooperating with this firm increases the likelihood that its partner will learn new routines and improve its innovative capabilities and technological performance.

From the perspective of the principal technology supplying firm, though, this attractiveness that it might have vis-à-vis its partner could also indicate certain risks in terms of leakage of knowledge and technologies. Certainly, there is always a risk of unintended knowledge leakage in the R&D interaction between alliance partners. However, when a firm is an attractive partner given its asymmetric innovative capabilities, there is a potentially higher risk of knowledge leakage as a by-product of the R&D alliance that goes beyond what is intended in the primary objective of the alliance. Hill (1992) refers to this unintended

knowledge leakage from the firm with higher levels of innovative capabilities as the risk of second-order diffusion of technological know-how. This second-order diffusion of know-how may enable the partner with lower innovative capabilities to acquire knowledge and improve its future innovative capabilities outside the range of what was intended by the alliance.

As indicated by Caves, Crookell & Killing (1983), it is practically impossible for a technology supplying firm to make an *ex ante* assessment of the future value of this second-order diffusion of technological know-how. In other words, that firm will find it extremely difficult if not impossible, to assess the exact value of alternative applications of that unintentionally transferred knowledge that a firm's partner can exploit to improve its innovativeness beyond the improvement stipulated in the contract. Given this limitation, the principal technology supplying partner in an R&D alliance is also expected to seek intellectual property control rights to mitigate the risk of this unintended leakage of technological know-how.

In the context of the appropriability hazards that the principal technology supplying partner faces with positive asymmetric innovative capabilities, we expect that firm to face the risk of technology leakage and to counter this risk by negotiating a number of intellectual property control rights. Moreover, the more innovative capabilities asymmetry with a partner plays a role in an R&D alliance, the more intellectual property control rights the principal technology supplying firm is expected to seek. Hence:

Hypothesis 1. *The larger the positive innovative capabilities asymmetry in an R&D alliance, from the perspective of the principal technology supplying firm, the more intellectual property control rights are allocated to that firm.*

The second condition that is expected to affect the allocation of intellectual property control rights refers to the scope of an R&D alliance that concerns both the focus and the breadth of the agreement. The focus of an alliance considers the different activities undertaken within the alliance, its breadth refers to the (potential) number of applications covered by the alliance.

Following previous research (Adegbesan & Higgins, 2009; Haeussler & Higgins, 2009; Higgins, 2007; Lerner, Shane & Tsai, 2003), we first reflect on the scope of an R&D alliance in terms of its focus on either of two stages in the innovation process: an early research phase and a later phase that concentrates on the actual development of new products and processes. A major characteristic of the first phase is that research, be it basic or applied, is experimental and full of uncertainties. At this stage, collaborating firms face a range of research options and, therefore, potentially a variety of directions for their joint research projects (Freeman & Soete, 1997; Nelson, 1961; 1982). In general, the open nature of the range of options that firms still have at this early stage indicates that there is little or no information on the concrete new products and processes that will eventually be developed and neither are firms able to assess the eventual innovation rents from this early stage of joint R&D (Haeussler, 2007). For R&D alliances that focus on this early phase, the implications are that collaborative research is, like internal research, characterized by high failure rates and the exact outcome of this kind of research is difficult to anticipate. As a consequence, early-stage research has fewer immediate commercial implications than more commercially-oriented activities such as the development and testing of new processes and products (Harrigan, 1985).

Development projects are far less uncertain in technological terms because they usually start from a predetermined set of technologies that will be developed further into commercial applications (Freeman & Soete, 1997). During this later phase, firms increasingly

focus on the implementation of innovations and the actual introduction of new products and processes. At this stage of the joint innovation process, which concentrates on the co-development of new products and processes, innovations can be more readily identified.

The above indicates that the allocation of intellectual property control rights is probably relevant for both stages of the R&D process within an R&D alliance. However, compared to the early stage innovation process that is characterized by research uncertainty, the later stage of product and process development has even more serious implications for the allocation of intellectual property rights as this stage is closer to the actual creation of innovation rents. Given the appropriability hazards that the principal technology supplying partner in an R&D alliance faces during the later stage of product and process development, we expect that firm to counter that risk by negotiating additional intellectual property control rights. Hence:

Hypothesis 2. *The later the innovation process stage of an R&D alliance, the more intellectual property control rights are allocated to the principal technology supplying partner.*

The second dimension of the scope of an R&D alliance refers to its breadth (Hansen & Higgins, 2008), i.e. the number of application areas that could be affected by the technology stipulated in the alliance contract. Following McGrath (1997), we take the number of potential applications of a technology as an *ex ante* indication of the expected demand for this technology and its products. In line with the Aghion & Tirole (1994) qualification of the GHM approach, a higher number of potential technology applications would put the principal technology supplying firm in an R&D alliance in a stronger *ex ante* bargaining position vis-à-vis its partner firm. However, a higher number of potential

technology applications could also increase future opportunities for the partner to later use or modify the technology beyond the initial intention of the contract. This could be considered harmful to the principal technology supplying firm and increase the appropriability hazards it will eventually face (Oxley, 1997). In case the technological foundation of an R&D alliance rests to a large extent on the technology supply of one partner, that principal technology supplying firm has a major incentive to secure the future innovation rents from the application of its technology. This also applies if these innovation rents are far from being manifest and still hidden as options within the realm of potential technology applications.

Considering the above, the principal technology supplying firm is expected to restrict the options for its partner to benefit from the R&D alliance, in excess of what was initially intended, by applying or modifying the technology and the underlying know-how into other areas. In order to accomplish this, the principal technology supplying firm is expected to increase its control concerning intellectual property rights in the alliance contract. In addition, a larger number of potential technology applications for an R&D alliance that probably increases the future returns from that alliance, might also put the principal technology supplying firm in a stronger bargaining position over these control rights. Hence:

Hypothesis 3. *The higher the number of potential technology applications for an R&D alliance, the more intellectual property control rights are allocated to the principal technology supplying partner.*

In recent years a number of, mostly theoretical, contributions have focused on the effect of exclusivity within inter-firm contracts, usually seen from an incomplete contracting perspective, as a major competitive condition for a range of topics such as moral hazard, relationship-specific investments, and hold-up (see Elfenbein & Lerner, 2009, for an

overview). Relatively few empirical studies have emerged that study the implications of exclusivity, i.e. the contractual prohibition of contract parties to engage in pre-determined activities with third parties. Anand & Khanna (2000) provide a broad empirical overview of the role that exclusivity plays in licensing contracts across a number of industries. Their findings suggest that exclusive contracts play a prominent role in the chemical industry, which includes pharmaceuticals, where intellectual property rights play an important role in the appropriation of innovation rents. Higgins (2007) finds that exclusivity in pharmaceutical alliances, based on exclusive marketing rights, has a marginally significant positive effect on the number of control rights allocated to pharmaceutical firms. Elfenbein & Lerner (2009) establish that internet portal providers, that play a role somewhat similar to the principal technology supplying partners in our analysis, receive more control rights in their alliances when they are prohibited from doing business with other firms.

Although the empirical literature, relevant in the context of our study, is limited, recent contributions (for instance Elfenbein & Lerner, 2009) suggest that a firm that engages in an alliance and that is contractually prohibited from engaging with third parties is likely to require more control rights than had it not signed a contract that excludes certain crucial activities. In essence, that firm compensates the lack of options in terms of collaborating with third parties with a demand for more control over its exclusive alliance. For the R&D alliances that we study this implies that when the principal technology supplying firm is by contract restricted in engaging in similar R&D activities with other firms, it is expected to negotiate a number of intellectual property control rights. These intellectual property control rights are crucial to secure its control over future innovation rents of its specific technological input that, by contract, it cannot appropriate by means of alternative R&D alliances. Hence:

Hypothesis 4. *The exclusivity of an R&D alliance, limiting the related R&D activities of the principal technology supplying partner with other parties, has a positive effect on the intellectual property control rights allocated to the principal technology supplying partner.*

DATA, METHODS, AND SAMPLE DESCRIPTION

Sample description

Our sample covers a set of slightly over 300 R&D alliance contracts in the US biopharmaceutical industry obtained from Pharmaventures, a UK-based information and consulting firm. Pharmaventures has identified thousands of alliances in the healthcare and biopharmaceutical sector in their PharmaDeals database. The collected deals are grouped into a number of categories, such as collaborative R&D, distribution/marketing, manufacturing/supply, and business acquisition. For each agreement, the PharmaDeals database provides information on for instance the names of the partners, type of contractual relationship, date deal signed, equity investment, relevant product areas and technology fields, press releases and, where available, the actual contracts. These actual contracts were obtained from the U.S. Securities and Exchange Commission (SEC) filings and Pharmaventures' clients.[1]

Our dataset covers R&D alliance contracts and additional information for the period 1996 through 2005. We collected information on alliances where the main focus is on R&D and for which PharmaDeals includes an actual legal document (contract). Using this sample we are able to generate a set of contracts in a homogeneous contracting space, which

[1] Publicly traded firms are required by the SEC to file material documents. Firms tend to interpret this requirement conservatively and often file contracts specifying alliances as amendments to 10-K, 10-Q, S-1 or 8-K statements. In addition, a number of state governments in the USA require privately held firms with employee stock options to file material documents, which are then made available to the public.

facilitates the comparison of key contract features across alliances. In this manner, we can be assured that variation in contracting terms and control rights does not come from a variation in the underlying industrial contracting environment.

The preliminary sample comprised 587 deals for the period 1996-2005. To avoid further unnecessary heterogeneity we excluded all the agreements where:

- one of the parties is a government agency or university
- the alliance is, as stated in the contract, a renegotiation or restatement of a previous alliance between the firms
- there is no R&D component to the alliance
- one firm has a controlling interest in the other firm (greater than 50%)
- contracts involve more than two parties.

The final contract database contains a set of 312 contracts which was reduced to 303 contracts due to various missing values. These contracts represent the first interaction between the firms as found in the dataset for the period 1996-2005.

The agreements include both US (domestic) contracts, i.e. the contracting parties are both US-based firms (180 alliances), and international contracts, i.e. a US-based firm collaborates with a non-US based firm (123 alliances). A total of 284 firms were involved in the 303 contracts and about 45% of the agreements were concluded between a biotech firm and a pharmaceutical or a chemical firm.

We collected additional information on for instance the size of firms, their R&D expenditures, their US patents, alliance experience, and prior ties between partners for the firms participating in these 303 deals. Our complete dataset combines information from PharmaDeals with data retrieved from firm annual reports, the Cooperative Agreements and Technology Indicators (CATI) database, Datastream, Compustat, Corptech, and the USPTO.

Dependent variable

Control rights. In previous studies, a variety of control rights allocated to either pharmaceutical firms or their biotech partners have been used as a dependent variable (Adegbesan & Higgins, 2009; Higgins, 2007; Hansen & Higgins, 2008; Haeussler & Higgins, 2009; Lerner, Shane & Tsai, 2003; Lerner & Merges, 1998). Our dependent variable differs from these previous studies in two dimensions. First, our sample covers a broader set of alliances than those between large pharmaceutical firms and small biotech firms and hence, regardless of the size of firms, we view the allocation of control rights from the perspective of the firm that, according to information provided by Pharmadeals, acts as the principal technology supplier within the alliance. Second, given the R&D nature of the alliances in our sample, we consider the intellectual property control rights as the main focus of our study. As a concrete measure of the allocation of control rights we take the actual fraction of a total number of nine intellectual property control rights allocated to the principal technology supplying firm within an alliance as the dependent variable. These nine intellectual property control rights are derived from a combination of categorizations of relevant control rights as found in Adegbesan & Higgins (2009), Higgins (2007), and Lerner & Merges (1998). See Appendix I for a list of intellectual property control rights in these contracts and Appendix II for examples of the actual text for these intellectual property control rights as found in sample contracts.

Independent variables

Innovative capabilities asymmetry. Given the importance of R&D as an input indicator of innovative capabilities and patents as an output indicator of these capabilities in an R&D and patenting intensive, high-tech industry, such as the biopharmaceutical sector, we measure innovative capabilities asymmetry in terms of both R&D intensity and patenting intensity.

R&D intensity indicates the degree to which a firm invests in its R&D as a major source of its future innovativeness. R&D intensity asymmetry indicates the difference between a principal technology supplying firm and its alliance partner in terms of the degree to which firms devote resources to develop their innovative capabilities.

For each firm we collected data on its R&D expenses in millions of US dollars. Average R&D expenses are calculated based on the R&D expenditures during the year of deal conclusion and the previous year. Assume A is the principal technology supplying firm and B its partner, this variable is defined as follows:

$$\text{R \& D Intensity Asymmetry} = \frac{(\text{R \& D Intensity A}) - (\text{R \& D Intensity B})}{(\text{R \& D Intensity A}) + (\text{R \& D Intensity B})} \quad (1)$$

Where R&D Intensity is defined as follows:

$$\text{R \& D Intensity} = \frac{\text{R \& D expenses}}{\text{net sales}} \quad (2)$$

If one would consider R&D asymmetry from the perspective of the larger firm in an alliance, a mere division of R&D expenses could be used to identify the R&D asymmetry between partners. However, as we take the perspective of the principal technology supplying firm, whether this firm is larger or smaller than its partner, such a division could prove to be statistically problematic.[2] Hence, we propose the variable given in equation (1), which generates a value between -1 and +1.[3]

[2] If the R&D expenses of the partnering firm equal or exceed those of the principal technology supplying firm, such division would generate a value between $[1,\rightarrow\rangle$. In the opposite case, when the R&D expenses of the principal technology supplying firm exceed those of the partnering firm, such division would fall in the domain $[0,1\rangle$.

[3] For some R&D alliances, one firm has an extremely high R&D intensity close or even higher than 1 whereas its partner has a more moderate R&D intensity. Well-known examples of this are found in the cooperation between small biotech research firms and large pharmaceutical firms. Depending on the number of cases in our sample, this very large asymmetry might drive the results of our analysis. In an additional unreported analysis, we control for the effect of an R&D intensity asymmetry above 2 or 3 times the standard

As a second indicator, we apply patenting intensity asymmetry as an output indicator of innovative capabilities asymmetry, measured in a similar way as for R&D intensity asymmetry. See Appendix IV for further details about this second indicator and the results of the statistical analysis.

Innovation process stage. The PharmaDeals database provides information on the stages of the innovation process underlying the deal. These stages refer to an early stage of collaborative research and a later stage of the co-development of new products. We use a dummy variable which equals 0 if the alliance contract concerns collaborative research and 1 if it refers to the co-development of products.

Potential technology applications. For each R&D alliance, PharmaDeals lists the number of possible technological interest areas for the products and/or technologies developed through that alliance, with a maximum of eight interest areas. We interpret these interest areas for a product and/or a technology in terms of the number of potential technology applications.

Exclusivity. For each alliance contract we checked the presence of any form of R&D exclusivity that includes obligations for the principal technology supplying partner. This exclusivity limits that firm in terms of the R&D activities to be undertaken with third parties in areas and/or fields as defined in the agreement. A dummy variable was included which equals 1 if there is an obligation on the side of the principal technology supplying firm concerning exclusivity and 0 otherwise.

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deviation of the difference between the R&D intensity of the technology supplying firm and the partner firm, by excluding these outliers (a maximum of 8.5 % of the sample). The results for the regressions without these outliers are similar to the results presented below.

Control variables

Size asymmetry. Contributions to the alliance literature point out that the size of firms participating in alliances and in particular the size difference between partners can play a role in the risk perception of firms during the partnership formation process (for instance Berg, Duncan & Friedman, 1982; Mytelka, 1991). This literature suggests that the size asymmetry of partners generates a higher appropriability hazard to the smaller firm due to the potentially opportunistic behavior of its larger partner. For instance, the literature on inter-firm cooperation through licensing indicates that when firms of different size engage in technology collaboration, larger firms attempt to dominate the agreement based on bargaining asymmetries that affect the terms of the agreement (Bessy & Brousseau, 1998; Caves, Crookell & Killing, 1983). Bargaining power asymmetries, largely influenced by size differences in inter-firm relationships, are also found to affect the control rights assigned to the dominant firm (Aghion & Tirole, 1994; Leiponen, 2008; Lerner & Merges, 1998). Following this line of argument, we expect that the size asymmetry of alliance partners might affect the allocation of intellectual property control rights.

To proxy size asymmetry, two variables are used both based on total assets. Assuming that firm A is the principal technology supplying firm and B its partner, the first variable is defined as follows:

$$\text{Size Asymmetry} = abs(\log(\text{Total Assets A}) - \log(\text{Total Assets B})) \quad (3)$$

Since this variable is by definition always larger than zero, we included a dummy variable which equals 1 if the total assets of the principal technology supplying firm exceed those of its partner and 0 otherwise.

Equity investment. Based on information provided by PharmaDeals, we noted for each R&D alliance contract, if the partner firm made an equity investment in the principal technology

supplying firm. Equity participation generates control in the alliance and this control might affect the allocation of intellectual property control rights (Hagedoorn, Cloodt & van Kranenburg, 2005; Oxley, 1997). A dummy variable was created which equals 1 if the contract involves the partner firm taking an equity stake in the principal technology supplying firm and 0 otherwise.

Alliance experience asymmetry. We calculated the average alliance experience for each firm per deal. Using the CATI database (see Hagedoorn, 2002), we obtained data on the prior R&D alliance experience of each firm, that is not reported in the PharmaDeals dataset, counting back five years from the year of deal conclusion. A five year window is widely accepted in the literature as an adequate period to measure the alliance experience of firms (see for instance Gulati, 1995). Although we do not expect a specific effect of the partner asymmetry in the experience with alliances, experience with previous alliances is known to affect the number of clauses and provisions that firms add to their contracts (Argyres, Bercovitz & Mayer, 2007; Mayer & Weber, 2005). This variable is defined as the difference between the alliance experience of the technology supplying firm and its partner.

Prior ties. Using the CATI database, we were also able to search for prior ties between alliance partners, that are not reported in the PharmaDeals dataset, counting back five years from the start of the R&D alliance (see also Gulati, 1995). Ryall & Sampson (2006) find that prior ties between partners lead to more detailed and complex contracts with a larger number of control rights and intellectual property rights clauses. Research by Fan (2008) indicates that prior ties between firms can lead to more control rights for one partner. Because in our dataset prior ties are mostly limited to one previous tie, this variable takes on a value 1 if there have been one or multiple prior ties between alliance partners and 0 otherwise.

Biotech firm. Dedicated biotech firms are known to have been major drivers of technological development in the biopharmaceutical industry (Adegbesan & Higgins, 2009; Higgins, 2007; Lerner & Merges, 1998). In that context, we control for the specific role that these biotech firms play as principal technology supplying firms in R&D alliances with other firms. If the principal technology supplying firm is a biotech firm and its partner is a non-biotech firm the dummy equals 1 and otherwise 0.

Financial constraints. In previous studies, the financial strength of in particular the biotech firm that participates in an alliance is regarded as an important determinant of the number of control rights it accumulates (for instance Higgins, 2007; Lerner & Merges, 1998). Aforementioned literature looks upon these biotech firms as the principal technology supplying partners. Ergo, from our more general perspective of the principal technology supplying partners, increased financial strength is also expected to augment the bargaining power of these firms and henceforth enable them to retain a larger share of intellectual property control rights in an R&D alliance, and vice versa. We proxy financial constraints of the principal technology supplying partners by taking the ROA (Return On Assets) ratio of these firms.

Alliance portfolio. The number of concurrent biopharmaceutical R&D alliance partners with which the principal technology supplying firm is involved at the time it is negotiating an R&D alliance, indicates the number of alternative partnering options it has. The larger the number of concurrent R&D alliance partners, the better the bargaining position of the principal technology supplying firm vis-à-vis it partner and this is expected to affect its ability to retain a larger share of intellectual property control rights (see also Adegbesan and Higgins, 2009). We measure this control variable as the number of alliance partners of the

principal technology supplying firm, excluding its current contract partner, in a three years period prior to the year of deal conclusion.

US partners. We include a dummy variable which takes a value of 1 if the partnering firms are headquartered in the same country (the US) and a value of 0 if otherwise (international deal). Firms are expected to have less information about foreign firms than about domestic firms and trust tends to emerge more readily between firms that share a similar social background, for instance those that are domestic partners (Zucker, 1986). This also suggests that behavioral uncertainty and opportunistic behavior may be more likely to arise in cross-border alliances affecting the governance of alliances (see also Hagedoorn, Cloodt & van Kranenburg, 2005). From the perspective of the principal technology supplying firm this implies that it has an incentive to seek more intellectual property control rights in an international R&D alliance.

Year. As the propensity to engage in R&D alliance contracts may vary during the period 1996-2005, we included year dummies. This year dummy equals 1 if the deal is concluded within the specific year and 0 otherwise.

Analysis

In the following, we present a Generalized Linear Model (GLM) with the fraction of intellectual property control rights allocated to the technology supplying firm as the dependent variable. We use GLM with a Bernoulli variance function and a logit link function utilizing maximum likelihood optimization with robust standard errors, as proposed by Papke & Wooldridge (1996) and applied amongst others by Adegbesan & Higgins (2009).

The contracts that we analyze represent the 'first interactions' between firms in the PharmaDeals dataset for the period 1996-2005 but a small number of firms appear in the dataset more than once. This occurs when firm A contracts with firm B and firm C separately, in that case both the AB and AC contracts are in the sample. Since firm A's behavior in contract AC is probably not independent of firm A's behavior in contract AB, error terms may not be independently distributed. Correlated error terms at the firm level might cause underestimated standard errors for firm attributes that are constant over multiple contracts. However, the independent distribution of the error terms in our econometric analysis is confirmed by the Durbin-Watson statistic and the Breusch-Godfrey test.

RESULTS

Table 1 provides the descriptive statistics and the correlation matrix. Additional information on the sample can be found in Appendix III. Correlations between the variables are moderate to very low and also the additional VIF statistics with values between 1.18 and 5.32 indicate that multicollinearity does not play a role in our analysis. Table 2 presents the results of the GLM regression analyses. Model 1 in table 2 refers to the basic model with only control variables. In models 2-5 each hypothesis-related independent variable is added, after which model 6 shows a regression with all the independent variables. An alternative procedure where hypothesis-related independent variables were added subsequently led to similar results. The size of the samples is sometimes smaller than 303 due to some additional missing values.

---------- insert table 1 about here ----------

Hypotheses 1 predicts that the larger the positive innovative capabilities asymmetry in an R&D alliance, seen from the perspective of the principal technology supplying firm, the more intellectual property control rights are allocated to that firm. This hypothesis is supported as we find the expected significant positive effects for both the R&D-based input indicator of innovative capabilities asymmetry, see models 2 and 6 in table 2, and the patent-based output indicator of innovative capabilities asymmetry, see Appendix IV (models 2 and 6). Hypothesis 2 states that, in terms of the focus of an R&D alliance, the later the innovation process stage of an R&D alliance, the more intellectual property control rights are expected to be allocated to the principal technology supplying firm. However, we find no support for this hypothesis neither in model 3 or 6 in table 2 nor in Appendix IV. We do find support for hypothesis 3 which predicts that the higher the number of potential technology applications for an R&D alliance, the more intellectual property control rights are allocated to the principal technology supplying firm. See models 4 and 6 in table 2 and Appendix IV, where we find the expected significant positive effect for the breadth of an R&D alliance technology scope. We also find support for hypothesis 4 which states that the exclusivity of an R&D alliance, that affects the principal technology supplying firm's alternative R&D options, has a positive effect on the intellectual property control rights held by that firm. Models 5 and 6 in table 2 and Appendix IV indicate the expected significant positive effect.[4]

[4] Since the number of intellectual property control rights and the presence of an exclusivity restriction on the part of the principal technology supplying firm are chosen simultaneously in contract negotiations, there is a potential endogeneity issue. Correcting for endogeneity in these specific econometric models is well known to be troublesome. In addition, methods based on instrumental variables (IV) are never unbiased and in smaller samples this bias can be substantial. Hence, we chose to check, by means of the Durbin-Wu-Hausman χ^2 -test (Davidson & MacKinnon, 1993), whether it is necessary to use instrumental variables or, stated otherwise, if estimates obtained through OLS are consistent or not.

We created a variable which equals 1 if both firms are in the biopharmaceutical industry and 0 otherwise, to serve as an instrument. It is expected that a principal technology supplying firm operating in the same industry as its partner of which the former is allowed to perform R&D activities with others in the same technological field/area, usually performs these activities with a third party also operating in the particular industry, thereby increasing

---------- insert table 2 about here ----------

Turning to the control variables, a small number of variables have a significant and positive influence on the fraction of intellectual property control rights allocated to the principal technology supplying firm. Previous research (for instance Fan, 2008; Ryall & Sampson, 2006) indicates that prior ties between partners lead to contracts where firms extend their new contracts with more details and additional clauses. In the context of the R&D alliance contracts that we study, such additional clauses seem to translate into in a larger fraction of intellectual property control rights allocated to the principal technology supplying partner. Also, as expected equity shares by partner firms, that increase their control, are balanced by an increase in the number of intellectual property control rights held by the principal technology supplying firm. In line with previous research (for instance Higgins, 2007; Lerner & Merges, 1998), we find a positive and significant value for the financial constraints measure in some of the models, in particular in the full model in table 2

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competition for the partner firm. In other words, consider principal technology supplying firm A and partner B, both operating in industry I and researching and/or developing technology T. If firm A would be allowed under the alliance contract to perform R&D activities with a third party, firm C, this firm would, with a large probability, also be found in industry I thereby diffusing knowledge about technology T to a potential competitor of partner B. Ergo, as firm A and B are operating in industry I, firm B has a major incentive to limit the outside R&D options of firm A. However, no effect of our instrument on intellectual property control rights is expected as, regardless of the industry, alliance partners are prone to try and maximize intellectual property control rights to capitalize on innovative rents.

The Durbin-Wu-Hausman χ^2 -test can be understood as follows. First, we regress our endogenous variable (exclusivity) on all exogenous variables plus our instrument (the industry variable discussed above) in our first-stage equation. Then, we save the residuals of this first-stage equation and include these in the second-stage equation with intellectual property control rights as dependent variable (for *Stata* a user-written module called *IVENDOG* might be acquired which performs a similar analysis after an IV regression (Baum, Schaffer & Stillman, 2007)). Under the H_0, IV and OLS are both consistent but OLS is more efficient while under the H_1 only IV is consistent. The Durbin-Wu-Hausman χ^2 -test failed to reject the null hypothesis of consistent estimates for exclusivity under normal OLS (results which are qualitatively similar to estimates obtained under the GLM and ordered logit models). Consequently, this provides additional confidence in the results obtained under the GLM estimator.

(see model 6). This indicates that as the financial strength of the principal technology supplying partner increases, so might its ability to negotiate a larger share of intellectual property control rights. In addition, we considered a number of interaction effects with the innovation process stage as a moderating condition (see also Adegbesan & Higgins, 2009). However, these interaction effects did not lead to any meaningful results.

To ensure the robustness of these results to model selection, we applied some alternative analyses with a simple count of the dependent variable combined with an ordered logit model. These analyses led to similar results. We also considered whether the particular bundle of intellectual property control rights, used in our analyses, drives the current results (Higgins, 2007). Instead of the nine intellectual property control rights reported so far (see Appendix I), we regenerated the analyses with dependent variables that sequentially exclude control rights that refer to payments and we combined exclusive and non-exclusive licensing. Although there are minor differences in the level of significance for individual variables, the main findings for these regressions are qualitatively consistent with the findings reported in table 2 and Appendix IV.

DISCUSSION AND CONCLUSIONS

In support of the Aghion & Tirole (1994) qualification of the GHM theorem, our research finds that the relative bargaining position of a principal technology supplying firm, seen as a major element of the inter-partner condition affecting control rights, plays a decisive role in the allocation of intellectual property control rights to that firm. Moreover, in the context of R&D alliances, it turns out that this relative bargaining position when based on asymmetries in innovative capabilities is more relevant than the general asymmetry in bargaining power based on firm size or market power differentials that was stressed in previous research (Aghion & Tirole, 1994; Leiponen, 2008; Lerner & Merges, 1998).

Seen from a different angle, the relative strength of a firm in terms of its innovative capabilities also makes it an interesting partner that could act as a source of unintended, second-order technology leakage (Hill, 1992). Our findings suggest that to counter this risk, the principal technology supplying partner in an R&D alliance, that has the bargaining power based on its innovative capabilities asymmetry, can negotiate intellectual property control rights that provide some control over the outcome of joint R&D and the appropriation of future innovation rents.

The second condition, referring to the scope of alliances affecting control rights, that is found to impact the allocation of intellectual property control rights is based on the technology breadth of an R&D alliance. This breadth concerns the number of possible application areas for the technology developed, extended or used in the alliance. The higher the number of potential technology applications, the higher the latent demand for this technology and the products based on this technology. Again this suggests that, following the Aghion & Tirole (1994) qualification of the GHM theorem, the principal technology supplying partner has a strong bargaining position for the allocation of intellectual property control rights. However, the number of potential technology applications also increases the risk that a firm's partner will later apply or modify the technology beyond the initial intention of the R&D alliance contract. In other words, this potential increases the appropriability hazards for the principal technology supplying firm. From both perspectives, as suggested by our findings, a principal technology supplying firm has an incentive to increase its control over the intellectual property of an alliance and future innovation rents by negotiating intellectual property control rights that reflect the number of potential technology applications for the R&D alliance.

The third condition to affect the allocation of intellectual property control rights is inspired by recent research on the exclusivity within inter-firm contracts, where exclusivity

refers to the contractual prohibition of contract parties to engage in pre-determined activities with third parties (see Elfenbein & Lerner, 2009). Exclusivity that prohibits a principal technology supplying partner in an R&D alliance from engaging with third parties is likely to create incentives for that firm to require more intellectual property control rights than had it not signed a contract that excludes certain external R&D activities. Our findings suggest that these intellectual property control rights are important for a principal technology supplying partner in an R&D alliance to secure its control over future innovation rents based on its specific technological input that, by contract, it cannot appropriate through alternative R&D alliances.

Interestingly, contrary to our findings for the scope of R&D alliances in terms of their breadth, we find no effect of the scope of these alliances in terms of the different stages in the innovation process on the allocation of intellectual property control rights. We anticipated that the development stage, where firms collaborate on the implementation of innovations closer to the introduction of new products and processes, would have an impact on the actual intellectual property control rights related to new products. As a consequence, we expected that, given the appropriability hazards that a principal technology supplying partner faces, this firm would counter this risk by negotiating additional intellectual property control rights. Our results do not indicate such an effect. However, we also find no support for an alternative explanation (Adegbesan & Higgins, 2009; Higgins, 2007; Lerner & Merges, 1998) which indicates that an R&D alliance at an early stage of basic and applied research would generate higher uncertainty about a range of future technological options. This uncertainty would then lead to larger information asymmetries between parties that in turn would affect the allocation of control rights.

The empirical findings of our study indicate strong support for our understanding of the effect that inter-firm asymmetries in innovative capabilities, the breadth of the technology

scope, and the exclusivity of R&D alliances have on the allocation of intellectual property control rights. In that context, we take the position of the principal technology supplying partner as the main focus of our analysis, based on the argument that the market structure and the related distribution of R&D alliances in the biopharmaceutical industry has changed. As argued in the introduction, this change implies that at the turn of the century, this industry demonstrates a less uneven distribution in the roles played by different categories of firms where an alliance between a large pharmaceutical firm and a small biotech firms has become only one of many options. Nevertheless, in this sample of R&D alliance contracts still about 45% of the alliances are between biotech firms (of which some have grown substantially over time) and any of the other firms. Hence, one might interpret our findings through an alternative explanation, based on previous studies (Adegbesan & Higgins, 2009; Higgins, 2007; Lerner & Merges, 1998), where by and large these biotech firms still act as the principal technology supplying partners in R&D alliances. As such, our analysis of the role of the principal technology supplying partner could then still be seen in the context of the 'classical' role of the biotech firm. Interestingly, our findings clearly show that there is no significant effect on the allocation of intellectual property control rights when a biotech firm acts as a principal technology supplying partner in an R&D alliance. This result does indeed indicate that the biopharmaceutical industry has become 'normalized' where the landscape of inter-firm R&D alliances has moved beyond the stereotype 'large pharma – small biotech' collaboration where the small biotech firm is the quintessential technology supplying partner of the industry.

Our findings suggest considerable opportunities for further research, opportunities that also point to some of the limitations of our current contribution. Future research could for instance consider other industries. Our current contribution only studies the allocation of intellectual property control rights in the biopharmaceutical industry. This industry is

important, it is an interesting high-tech sector, but other high-tech industries as well as medium and low-tech industries are also relevant industrial settings for the study of intellectual property control rights. We do find some interesting results but it is of the essence to further assess these findings in the light of other industries where intellectual property rights play a different role (see Cohen, Nelson & Walsh, 2000). In addition, our work is based on the content of the actual contracts that bind partners and we can measure the number of *ex post* intellectual property control rights in each contract. However, we have no understanding of the *ex ante* preferences of firms for particular control rights or the weight that partners assign to each of these control rights. As such, we have no knowledge regarding the extent to which these control rights were subject to negotiations between partners and how intellectual property control rights are assigned to partners. Knowledge of both the *ex ante* preferences and the *ex post* allocation of control rights would already reveal some insights of the negotiation process. Also, survey research where partners are questioned on the process of contract negotiations could provide us with useful additional information on the actual importance of individual control rights for alliance partners. Finally, although a substantial share of the partners involved in the alliances and contracts that we studied are not from the USA, these contracts are typically relevant in the US context as they fall under the US legal regime. Given the current international context of many alliances, another interesting topic for future research is to be found in the international comparison of alliance contracts, intellectual property control rights, and related legal practice in major judicial environments where these contracts are registered.

Appendix I Intellectual property control rights

Previous studies (Adegbesan & Higgins, 2009; Hansen & Higgins, 2008; Haeussler & Higgins, 2009; Higgins, 2007; Lerner & Merges, 1998; Lerner, Shane & Tsai, 2003) identified a range of general control rights found in alliance contracts. Given the R&D nature of the alliance contracts that we analyze, we selected nine control rights that are particularly relevant for the intellectual property rights of firms. For each alliance contract, we scanned the contract for clauses that indicate whether a particular intellectual property control right is given to the principal technology supplying firm. Information on these intellectual property control rights were obtained by means of a special text analysis program.

The list below provides the nine intellectual property control rights and the actual measures for these control rights, used to search the contracts for relevant text and clauses.

- *Inventions made by the principal technology supplying firm, during the agreement, will be owned by that firm.*

  All relevant inventions made by the principal technology supplying firm in the context of the alliance will be owned by that firm.
- *Principal technology supplying firm is the owner of specific inventions.*

  Specific inventions, relating to specific technology areas specified in advance, will be owned by the principal technology supplying firm.
- *Principal technology supplying firm is the owner of trademarks.*

  The principal technology supplying firm owns trademarks prior to entering the agreement and it will own trademarks developed during the alliance.
- *Principal technology supplying firm has the right to sublicense.*

  The principal technology supplying firm has the right to grant sublicense to third parties.
- *Principal technology supplying firm grants its partner an exclusive license.*

The partner firm receives an exclusive license from the principal technology supplying firm that restricts the options for this partner and that specifies the ownership of the technology by the principal technology supplying firm.

- *Principal technology supplying firm grants its partner a non-exclusive license.*
  The partner firm receives a non-exclusive license that specifies the ownership of the technology by the principal technology supplying firm.
- *Principal technology supplying firm receives an access fee from its partner.*
  Access fee can be a one time fee, an upfront license fee or a technology fee.
- *Principal technology supplying firm receives royalty payments from its partner.*
  The partner firm has an obligation to pay the principal technology supplying firm royalties, usually expressed as a percentage of net sales.
- *Principal technology supplying firm receives payments upon achieving targets.*
  The partner firm has an obligation to pay the principal technology supplying firm in return for the latter achieving targets, this refers to benchmark payments, incentive payments or milestone payments.

Correlations among these measures as found in the sample of R&D alliance contracts do not exceed the usual (0.7) cut off value.

Appendix II Examples of intellectual property control rights clauses

Intellectual property control rights	Examples
1. Inventions made by the principal technology supplying firm, during the agreement, will be owned by that firm.	'AHP shall own all inventions within the scope of the Research Program or the AHP Discovery Program made solely by its employees.'
2. Principal technology supplying firm is the owner of specific inventions	'Vyrex shall solely own the entire right and title in all CD- TaggingTM Improvements and CD-TaggingTM Vectors, whether or not patentable (and any patent or other intellectual property rights therein), which are conceived or produced during and in the performance of the Program.'
3. Principal technology supplying firm is the owner of trademarks	'ACLARA, at its expense, will be responsible for the selection, registration and maintenance of all trademarks that it employs in connection with Oasis LabCard chips, which will be prominently displayed on Oasis LabCard chips sold by PACKARD and will own and control such trademarks. Nothing in this agreement will be construed as a grant of rights, by license or otherwise, to PACKARD to use such trademarks for any purpose other than co-promotion as provided in this Agreement.'
4. Principal technology supplying firm has the right to sublicense	'Genentech hereby grants to Dendreon a nonexclusive royalty bearing license with right of sublicense through multiple tiers of sublicensees under Genentech Patent Rights, Genentech Know-how and Genentech's interest in the Joint Patent Rights to use, sell, offer for sale and import Licensed Products in the Field in the Dendreon Territory.'
5. Principal technology supplying firm grants its partner an exclusive license	'Subject to the terms and conditions of this Agreement and during the term hereof, InSite hereby grants B&L an exclusive product license or sublicense under the Patents and unpatented Know-How to manufacture, have manufactured, use, import, sell and sublicense the Timolol Product in the Territory.'
6. Principal technology supplying firm grants its partner a non-exclusive license	'Geron hereby grants to Merck a non-exclusive license in the Territory under the Geron Patent Rights, Geron Know-How, Geron Program Patent Rights and Geron's interest in Joint Program Patent Rights and Geron's interest in Program Know-How, and

	Materials, solely for the purpose of conducting research in those aspects of the Research Program pertaining to DC Products and DC/Adeno/DNA Therapies.'
7. Principal technology supplying firm receives an access fee from its partner	'Within ten (10) calendar days of the Effective Date, Roche Bioscience shall pay Tularik a technology access fee equal to [*]. Such technology access fee shall be non-refundable and shall not be credited against royalties payable to Tularik under this Agreement.'
8. Principal technology supplying firm receives royalty payments from its partner	'BMS shall pay Cubist a royalty based on the Net Sales of each Covered Product as provided in section 3.6 hereof. Such royalty shall be paid with respect to each country of the world from the date of the First Commercial Sale of such Covered Product in each country for the duration of the Royalty Term with respect to such country'
9. Principal technology supplying firm receives payments upon achieving targets	'Genzyme shall pay to Dyax an amount of ten million dollars ($10,000,000) on the first full approval by the U.S. FDA of an NDA for the use of a Collaboration Product for any therapeutic indication'

Appendix III Summary statistics of sample

Panel A: Distribution of Observations by Year	1996	1997	1998	1999	2000
Number of contracts signed in year	22	39	27	44	58
	2001	2002	2003	2004	2005
	42	26	25	14	6

Variable	Mean	Median	Std. Dev.	Min	Max
Panel B: Principal technology supplying firm and partnering firm characteristics					
Principal technology supplying firm					
Total Assets ($)	78.6	7.1	475.6	0.2	6786.2
Net Sales ($)	37.1	1	217.6	0	2129.6
R&D Expenses ($)	22.4	1.8	205.8	0	3290.1
Net Income ($)	-2	-1.4	78.8	-1206.1	432.6
Alliance portfolio	2.2	1	3.1	0	22
5-Year Number of Patents	45.7	12	104.3	0	848
5-Year Alliance Experience	4.1	2	5.4	0	36
Partnering firm					
Total Assets ($)	1035.2	280.6	1407.9	0.1	5372.1
Net Sales ($)	788.4	160.6	1088.8	0	4497.8
R&D Expenses ($)	259	37.1	853.5	0	8669.1
Net Income ($)	122.5	10.7	194.4	-79.8	632.2
Alliance portfolio	8.1	4	9.9	0	40
5-Year Number of Patents	414.9	173	565.5	0	3547
5-Year Alliance Experience	14	7	16.6	0	67
Panel C: Alliance contract characteristics					
Innovation process stage					
Collaborative research (%)	0.59			0	1
Co-development (%)	0.41			0	1
Alliance characteristics					
Prior ties (%)	0.47			0	1
US Partners (%)	0.59			0	1
Potential Applications	2.2	2	1.3	1	8
Exclusivity (%)	0.1			0	1
Equity investment (%)	0.18			0	1
Biotech firm (%)	0.46			0	1
Allocation of control rights					
Control rights to principal technology supplying firm (out of 9)	3.5	4	1.9	0	8

Note: The Dollar amounts shown in 'Panel B' are in 0000's.

Appendix IV Analysis of innovative capabilities asymmetry based on patenting intensity.

Patenting intensity as such indicates the degree to which a firm, given its size, has successfully obtained patents as a major output of its innovative activities. Patenting intensity asymmetry refers to the difference between a principal technology supplying firm and its alliance partner in terms of the degree to which these firms have developed their innovative capabilities from an innovation output perspective.

For each firm we collected data on the number of its US patents obtained in a five year period prior to signing the alliance contract. Assume A is the principal technology supplying firm and B its partner, this variable is defined as follows:

$$\text{Patenting Intensity Asymmetry} = \frac{(\text{Patenting Intensity A}) - (\text{Patenting Intensity B})}{(\text{Patenting Intensity A}) + (\text{Patenting Intensity B})} \qquad (4)$$

Where Patenting Intensity is defined as follows:

$$\text{Patenting Intensity} = \frac{\text{Number of patents}}{\text{net sales}} \qquad (5)$$

As with the R&D input indicator of innovative capabilities asymmetry, we take the perspective of the principal technology supplying firm, whether this firm is larger or smaller than its partner. Hence, we propose the variable given in equation (4), which generates a value between -1 and +1.

The analysis with patenting intensity asymmetry as an indicator of innovative capabilities asymmetry is presented below. The number of observations is somewhat larger than for the analysis with R&D intensity asymmetry as an indicator of innovative capabilities asymmetry.

For about 11% of the observations in our sample there is no patent registered with the US PTO by at least one of the R&D alliance partners. In that case one or both partners had

either no patent at all or not applied for a patent during a window of five years preceding the alliance. These 11% might alter our results since in these cases the value of our Patent Intensity Asymmetry measure always takes on a value of 1 or -1, regardless of the Patent Intensity of firm A or B respectively. Therefore, in an unreported analysis, we exclude the 11% where no patent was registered with the USPTO by at least one partner. Results for these regressions are similar to the results presented below.

Yet another alternative indicator of innovative capabilities that we considered is based on the frequently used measure of citation weighted patent counts, to control for the quality or value of patents. However, apart from the fact that missing values for patent counts implies that we cannot find patent citations for these firms, which already at the start reduces our sample with more than 10%, there is a larger additional problem with the citation time lags that affect the current sample period. The relevant period between patent granted and patent citation covers a period of between two and eight years, with an additional period of at least two years between patent application and patent granted (Hall, Jaffe, & Trajtenberg, 2005). Given the data available at the USPTO, we would, even if we limit the citation lag to a maximum of five years, only be able to include citation weighted patent counts for the period 1996-1998 which would decrease the size of our sample with an additional 70%.

Given such limitations, we present the results of our analysis with patenting intensity asymmetry, based on patent counts, as a second indicator of innovative capabilities asymmetry. These results are, with only minor differences, quite similar those presented in table 2.

Table IV.1 Alternative estimation results of generalized linear model (GLM)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable						
Innovative capabilities asymmetry (Patents)		0.161*				0.190**
		(0.087)				(0.085)
Innovation process stage			-0.042			-0.015
			(0.108)			(0.113)
Potential technology applications				0.123***		0.123***
				(0.034)		(0.035)
Exclusivity					0.328**	0.350**
					(0.158)	(0.159)
Size asymmetry	-0.012	-0.022	-0.011	-0.009	-0.011	-0.020
	(0.028)	(0.032)	(0.028)	(0.027)	(0.028)	(0.031)
Size asymmetry dummy	-0.131	-0.069	-0.129	-0.126	-0.144	-0.060
	(0.156)	(0.172)	(0.156)	(0.150)	(0.155)	(0.163)
Equity investment	0.291**	0.311**	0.293**	0.291**	0.269**	0.292**
	(0.125)	(0.126)	(0.127)	(0.120)	(0.127)	(0.125)
Alliance experience asymmetry	-0.002	-0.004	-0.002	-0.002	-0.002	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Prior ties	0.418***	0.408***	0.414***	0.357***	0.419***	0.349***
	(0.104)	(0.106)	(0.105)	(0.103)	(0.103)	(0.104)
Biotech firm	0.026	-0.030	0.024	0.032	0.013	-0.048
	(0.108)	(0.107)	(0.108)	(0.106)	(0.108)	(0.104)
Financial constraints	0.174	0.206	0.172	0.177	0.166	0.204
	(0.131)	(0.135)	(0.132)	(0.132)	(0.131)	(0.135)
Alliance portfolio	-0.002	0.003	-0.003	-0.006	-0.002	-0.002
	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)	(0.018)
US partners	0.092	0.091	0.086	0.080	0.077	0.059
	(0.106)	(0.107)	(0.108)	(0.106)	(0.105)	(0.108)
Year 2005 dummy	0.571	0.496	0.578	0.437	0.635	0.423
	(0.389)	(0.387)	(0.387)	(0.408)	(0.392)	(0.407)
Year 2004 dummy	0.643***	0.606***	0.645***	0.661***	0.718***	0.689***
	(0.204)	(0.210)	(0.205)	(0.208)	(0.213)	(0.217)
Year 2003 dummy	0.262	0.206	0.270	0.274	0.328	0.284
	(0.195)	(0.199)	(0.196)	(0.196)	(0.202)	(0.203)
Year 2002 dummy	-0.054	-0.061	-0.052	-0.020	0.014	0.032
	(0.216)	(0.217)	(0.216)	(0.208)	(0.221)	(0.212)
Year 2001 dummy	-0.375*	-0.389*	-0.377*	-0.353*	-0.355*	-0.352*
	(0.209)	(0.213)	(0.209)	(0.205)	(0.207)	(0.203)
Year 2000 dummy	-0.283	-0.298	-0.279	-0.297*	-0.220	-0.247
	(0.184)	(0.191)	(0.184)	(0.180)	(0.190)	(0.188)
Year 1999 dummy	-0.172	-0.232	-0.179	-0.207	-0.157	-0.261
	(0.186)	(0.187)	(0.187)	(0.178)	(0.185)	(0.179)
Year 1998 dummy	-0.099	-0.126	-0.100	-0.085	-0.050	-0.062
	(0.208)	(0.207)	(0.206)	(0.203)	(0.221)	(0.213)
Year 1997 dummy	-0.053	-0.036	-0.055	-0.058	0.009	0.033
	(0.180)	(0.185)	(0.180)	(0.175)	(0.191)	(0.189)
Constant	-0.562***	-0.582***	-0.539**	-0.796***	-0.625***	-0.879***
	(0.201)	(0.203)	(0.213)	(0.208)	(0.209)	(0.232)
Log pseudolikelihood	-141.861	-136.801	-141.847	-141.036	-141.544	-135.568
N	303	293	303	303	303	293
GLM model, logit link function, bernoulli variance function, robust standard errors in parentheses						
* significant at 10%; ** significant at 5%; *** significant at 1%						

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Table 1 Descriptive statistics, mean, standard deviation (SD), and bivariate correlations for all variables, n=290

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Control rights	0.394	0.213	1.000														
2. Innovative capabilities asymmetry (R&D)	0.477	0.608	0.201	1.000													
3. Innovative capabilities asymmetry (Patents)	0.463	0.718	0.134	0.449	1.000												
4. Innovation process stage	0.409	0.493	-0.037	-0.014	-0.027	1.000											
5. Potential technology applications	2.185	1.286	0.219	0.048	-0.053	-0.134	1.000										
6. Exclusivity	0.099	0.299	0.096	-0.089	-0.118	-0.131	0.068	1.000									
7. Size asymmetry	3.740	2.111	0.060	0.290	0.348	-0.001	-0.045	-0.042	1.000								
8. Size asymmetry dummy	0.178	0.383	-0.091	-0.401	-0.479	-0.011	0.020	0.064	-0.355	1.000							
9. Equity investment	0.182	0.386	0.139	0.068	-0.046	0.062	0.020	0.077	0.016	-0.050	1.000						
10. Alliance experience asymmetry	-9.904	17.296	-0.063	-0.396	-0.090	0.043	0.003	0.013	-0.387	0.213	0.001	1.000					
11. Prior ties	0.472	0.500	0.222	0.012	-0.020	-0.158	0.188	0.028	-0.020	-0.024	0.076	-0.099	1.000				
12. Biotech firm	0.462	0.499	-0.009	0.184	0.283	-0.071	-0.011	0.035	0.311	-0.255	-0.091	-0.249	-0.003	1.000			
13. Financial constraints	-0.340	0.426	0.044	-0.263	-0.137	-0.037	0.011	0.035	-0.178	0.225	-0.069	0.163	0.049	-0.042	1.000		
14. Alliance portfolio	2.176	3.149	0.009	-0.229	-0.064	-0.111	0.100	0.007	-0.052	0.274	-0.118	0.321	0.167	0.009	0.240	1.000	
15. US partners	0.594	0.492	0.028	0.060	-0.087	-0.135	0.023	0.091	-0.127	0.152	0.093	0.072	-0.019	-0.205	-0.057	-0.107	1.000

Table 2 Estimation Results of Generalized Linear Model (GLM)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable						
Innovative capabilities asymmetry (R&D)		0.334***				0.348***
		(0.105)				(0.106)
Innovation process stage			-0.042			0.007
			(0.108)			(0.112)
Potential technology applications				0.123***		0.116***
				(0.034)		(0.036)
Exclusivity					0.328**	0.390**
					(0.158)	(0.164)
Size asymmetry	-0.012	-0.015	-0.011	-0.009	-0.011	-0.011
	(0.028)	(0.030)	(0.028)	(0.027)	(0.028)	(0.029)
Size asymmetry dummy	-0.131	-0.009	-0.129	-0.126	-0.144	-0.020
	(0.156)	(0.160)	(0.156)	(0.150)	(0.155)	(0.152)
Equity investment	0.291**	0.262**	0.293**	0.291**	0.269**	0.231*
	(0.125)	(0.128)	(0.127)	(0.120)	(0.127)	(0.127)
Alliance experience asymmetry	-0.002	0.001	-0.002	-0.002	-0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Prior ties	0.418***	0.413***	0.414***	0.357***	0.419***	0.356***
	(0.104)	(0.103)	(0.105)	(0.103)	(0.103)	(0.102)
Biotech firm	0.026	0.006	0.024	0.032	0.013	-0.008
	(0.108)	(0.107)	(0.108)	(0.106)	(0.108)	(0.104)
Financial constraints	0.174	0.271*	0.172	0.177	0.166	0.280**
	(0.131)	(0.139)	(0.132)	(0.132)	(0.131)	(0.140)
Alliance portfolio	-0.002	0.000	-0.003	-0.006	-0.002	-0.006
	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)	(0.018)
US partners	0.092	0.073	0.086	0.080	0.077	0.046
	(0.106)	(0.106)	(0.108)	(0.106)	(0.105)	(0.108)
Year 2005 dummy	0.571	0.842***	0.578	0.437	0.635	0.813**
	(0.389)	(0.313)	(0.387)	(0.408)	(0.392)	(0.326)
Year 2004 dummy	0.643***	0.736***	0.645***	0.661***	0.718***	0.836***
	(0.204)	(0.209)	(0.205)	(0.208)	(0.213)	(0.220)
Year 2003 dummy	0.262	0.277	0.270	0.274	0.328	0.370*
	(0.195)	(0.195)	(0.196)	(0.196)	(0.202)	(0.202)
Year 2002 dummy	-0.054	0.075	-0.052	-0.020	0.014	0.186
	(0.216)	(0.215)	(0.216)	(0.208)	(0.221)	(0.214)
Year 2001 dummy	-0.375*	-0.311	-0.377*	-0.353*	-0.355*	-0.263
	(0.209)	(0.219)	(0.209)	(0.205)	(0.207)	(0.209)
Year 2000 dummy	-0.283	-0.204	-0.279	-0.297*	-0.220	-0.139
	(0.184)	(0.194)	(0.184)	(0.180)	(0.190)	(0.197)
Year 1999 dummy	-0.172	-0.145	-0.179	-0.207	-0.157	-0.148
	(0.186)	(0.189)	(0.187)	(0.178)	(0.185)	(0.182)
Year 1998 dummy	-0.099	-0.032	-0.100	-0.085	-0.050	0.045
	(0.208)	(0.208)	(0.206)	(0.203)	(0.221)	(0.217)
Year 1997 dummy	-0.053	0.036	-0.055	-0.058	0.009	0.113
	(0.180)	(0.184)	(0.180)	(0.175)	(0.191)	(0.193)
Constant	-0.562***	-0.702***	-0.539**	-0.796***	-0.625***	-1.001***
	(0.201)	(0.205)	(0.213)	(0.208)	(0.209)	(0.231)
Log pseudolikelihood	-141.861	-135.404	-141.847	-141.036	-141.544	-134.204
N	303	291	303	303	303	291
GLM model, logit link function, bernoulli variance function, robust standard errors in parentheses						
* significant at 10%; ** significant at 5%; *** significant at 1%						