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Joint Patenting in R&D Alliances: Control Rights and Resource Attributes

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Abstract
In this paper, an attempt is made to provide a clearer understanding of the motives that lead firms to share intellectual property rights in their innovative efforts, through joint patents in R&D alliances. We test our hypotheses on a sample of 116 biotechnology R&D alliances, and explain variation in joint patenting activities. Our results show that the characteristics of the resources held by the firms, and the ex-ante allocation of control rights, can influence joint patenting activity.

Key words: Joint Patent, Resource-Based View, Control Rights

INTRODUCTION

Why do some firms choose to share foreground intellectual property rights through joint patents while others do not? Under joint ownership, the contracting parties share ownership of and the property rights to the same asset. Thus, joint patenting can be a way to allocate appropriable control rights and hence establish the share of value created through collaboration.

Joint patenting and the sharing of intellectual property rights also raise the issue of the firm's boundaries (Arora & Merges, 2004). This has substantial economic implications due to the many different entities that can hold rights (Kim & Mahoney, 2002). A joint patent must be understood as embodying a partner firm's willingness to give another firm the right to use and transfer all rights to an output through sale or license. Joint patents increase the other party's freedom of action beyond the temporary R&D collaborative process, thus creating a future competitor. For instance, Belderbos, Faems, Leten, and Van Looy (2010) find that a firm's financial performance decreases as the proportion of joint patents in the patent portfolio increases.

Joint patents have been analyzed in an ad hoc joint effort involving specific research projects (Belderbos et al., 2010; Khoury & Pleggenkuhle-Miles, 2011; Rocha, 1999). Surprisingly, the empirical literature on control rights allocation shows that cooperation plays an insignificant role (Elfenbein &Lerner, 2003; Hagedoorn, van Kranenburg & Osborn, 2003; Leiponen, 2008; Lerner & Merges, 1998). For instance, Lerner and Merges (1998) stress that "the most profound effect on the allocation of control rights, at least in technology alliances [...], is the financial condition of the R&D firm, rather than mutual concern about maximizing joint value" (Lerner & Merges, 1998: 153). Expanding on these studies, Leiponen (2008) points out that ex-post control rights are allocated according to not only relative ability to innovate or contribute to the project, but also bargaining position. Hagedoorn et al. (2003) show that once companies have built up some experience in joint patenting with other companies, they continue to do so. Adegbesan and Higgins (2010) find that value appropriation is contingent on the circumstances surrounding the alliance creation. These studies suggest that both alliance-initial conditions and contextual factors may explain joint patenting activity.

Two perspectives from the literature may provide insight into why some firms choose to share foreground intellectual property rights through joint patents. Property rights theory distinguishes two types of control rights: specific and residual (Grossman & Hart, 1986). Specific rights, as defined by the contract terms, restrict what the other party can do with relationship-specific assets (Elfenbein & Lerner 2003; Grossman & Hart, 1986). Increasing the number of specified control rights in a contract allows the set of residual control rights to be restricted. Residual rights, which remain uncontracted, are essentially property rights (Grossman & Hart, 1986). In the resource-based view (RBV), residuals rights can be assimilated to the firm's owned resources. Resource-based theory implicitly proposes that ownership is secure due to the inherent attributes of its resources (Kim & Mahoney, 2005). More specifically, specialized complex resources are defined as valuable, rare, inimitable, and non-substitutable (Peteraf, 1993). They are capable of generating economic rents for the firm

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that owns them, and they limit ex-post competition (Mahoney, 2001; Peteraf, 1993). In R&D alliances, firms may manage these resources so as to retain the property rights, given the potential for opportunistic behavior by partners (Das & Teng, 1996; Williamson, 1993).

Although joint patenting is an important aspect of intellectual property protection, it has received little attention in the managerial literature (Hagedoorn et al., 2003). This paper examines how the property rights and resource-based theories complementarily explain joint patenting activity. First, we argue that the ex-ante allocation of specific control rights may influence the ex-post allocation of control rights. Second, we extend RBV to the division of intellectual property in alliances by arguing that a firm's resource attributes explain the ex-post allocation of control rights. We test our hypotheses in the empirical setting of US biotechnology research and development (R&D) alliances. The biotech industry offers an instructive environment, given that R&D collaborations provide the most promising means of survival. Moreover, this industry is characterized by rapid technological development and a high degree of intellectual property rights protection. Furthermore, the percentage increase in jointly owned intellectual property rights, especially in the form of joint patents, is specific to the US biotechnology and pharmaceutical sectors, where 8% of patents are co-assigned (Khoury & Pleggenkuhle-Miles, 2011). Our findings highlight the influence of control rights allocation and owned resources on the probability of joint patenting activity in R&D alliances.

R&D alliances and ex-post property rights

The benefits of R&D alliances are evident: they allow co-financing R&D efforts so that firms can reduce uncertainty and costs (Sakakibara, 1997), share skills, and increase their innovation capacity (Khoury & Pleggenkuhle-Miles, 2011). However, they are complex organizational arrangements that involve risks (Das & Teng, 1996). These risks are related to transaction and control costs, the partner's potential opportunistic behavior (Williamson, 1985), and asymmetric profitability expectations for returns on innovations (Helm & Kloyer 2004). At the end of the collaborative process, the division of rights may result in mainly individual intellectual property (IP) ownership or joint IP ownership. Joint IP ownership and the sharing of intellectual property rights raise the issue of the firms' boundaries. Under proprietary rights theory, a firm is a collection of assets over which managers have residual control rights, i.e., the right to decide how the assets are to be used under circumstances that are not specified in a contract (Grossman & Hart, 1986). The boundaries of the property rights stretch beyond the boundaries of the organization.

Both property rights and resource-based theory emphasize factors that may affect the allocation of residual control rights. The premise is that firms face an "appropriability hazard" due to contract incompleteness. When two or more parties are involved in a technological development or research project and are investing critical resources into the collaborative process, delineating each party's respective property rights becomes difficult (Kim & Mahoney, 2005). Thus, the ex-ante contract does not specify a clear division of the ex-post surplus, and remains incomplete (Grossman & Hart, 1986). Moreover, in situations where a large surplus is to be divided ex post, the contractual relationship between two separately owned firms will be hindered by opportunistic and inefficient behavior. Klein, Crawford, and Alchian (1978) emphasize the benefits of achieving control in response to this underlying uncertainty by carefully organizing the R&D activities and the alliance's governance structure (Teece, 1986; Pisano, 1990; Oxley, 1997). The greater the appropriability hazard in interfirm partnering, the more companies will prefer a joint venture mode (Oxley, 1997). However, the literature has not explicitly recognized that contractual mechanisms, including property rights allocation, create incentives and influence behavior (Leiponen, 2008; Kloyer, 2011). Some research proxies value appropriation with the share of a key subset of ex-ante alliance control rights won by the partners (Adegbesan & Higgins, 2010). There is a small body of work in the strategic management literature that focuses on the determinants of control rights allocation (Adegbesan & Higgins, 2010; Lerner & Merges, 1998; Leiponen, 2008). These studies are based on theoretical economic models. Modern economists have explicitly analyzed the incentive implications of ownership allocation (Grossman & Hart, 1986; Hart & Moore, 1990), where ownership is defined as residual control rights, and contract incompleteness creates the need to allocate these residual control rights. A partner's incentive to invest in R&D and in the relationship is contingent upon guarantees of some claim to the expected future income attributable to the discovery. These guarantees depend on the ownership structure. In the Grossman-Hart-Moore property rights framework (GHM model), the owner of the assets gains the bargaining power to hoard the larger part of the project surplus. The option to purchase residual control rights is not particularly relevant to biotechnology firms, however. These firms do not generate positive cash flow from their operations, and consequently they often lack the money to buy the assets they ought to own (Lerner & Mergers, 1998; Robinson & Stuart, 2003). In Aghion and Bolton's model (1992), co-ownership is suboptimal compared to unilateral and contingent ownership, given that it exacerbates ex-post hold-up problems, which generally lead to an under-supply of effort. Aghion and Tirole's model (1994) features two polar cases: the ex-ante bargaining power of the R&D unit versus that of the consumer firm. Ownership of the research output will be efficiently allocated when the ex-ante bargaining power of the research unit is greater than that of the consumer firm. In this case, it is suggested that the marginal impact of the research unit's effort on the innovative output is greater than the marginal impact of the customer's investment, and the research unit will receive the property rights. Two factors should determine how residual control rights are allocated: the degree of underinvestment by either or both of the parties, and the relative ex-ante bargaining power of the two parties (Aghion & Tirole 1994).

The second research avenue emphasizes the firm's resources. "Firm resources include all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness" (Barney, 1991: 101). The resource-based view (RBV) has been widely used to examine strategic alliance formation, because firms essentially use alliances to gain access to other firms' valuable resources (Eisenhhardt & Shoonoven, 1996). McEvily and Chakravarthy (2002) empirically demonstrate that resource characteristics can prolong competitive advantage. The underlying assumption is that "the ownership of certain resources automatically leads to generation of economic rents" (Kim & Mahoney, 2002: 234). Nevertheless, according to Amit and Shoemaker (1993), under resource-based theory, economic rents are understood to be appropriated by the firm, and not by the individual resource: "Resources are converted into final products or services by using a wide range of other firm assets" (Amit & Shoemaker, 1993: 35). Consequently, insofar as collaboration requires pooled resources and means, there is less inherent protection of resources in alliance relationships. Therefore, the allocation of property rights at the end of the collaborative process may allow the optimal management of resources to increase the firm's competitive advantage (Peteraf, 1993). Residual control rights may impact the choice to share intellectual property rights, and hence patent sharing.

Ex-Ante Specific Control Rights and Joint Patenting Activity

The alliance design research that addresses the contractual provisions firms use to structure their relationships largely views contracts as the outcome of a combination of clauses (Lerner & Merges, 1998; Reuer & Ariño, 2007) that varies in complexity. The more complex the contract, the more contractual provisions it includes (Parkhe, 1993).

One important set of contractual provisions concerns alliance control rights. Control rights "may take many forms, including restrictions on the nature of investments into the productive asset and restrictions on how the asset can be used once investments have been sunk" (Elfenbein & Lerner, 2003: 358). Specific control rights can convey the firm's bargaining power and confer control over activities that affect the allocation of the value to be created by the alliance (Lerner & Merges, 1998). The ex-ante allocation of control rights reflects the ex-post allocation of control rights: in other words, how to split future value in the present (Abegbesan & Higgins, 2010; Leiponen, 2008). Consequently, although IP ownership is addressed in the last step of IP management in alliances, several researchers suggest that ownership decisions are often made early in the formation stage of R&D alliances (Adegbesan & Higgins, 2010; Leiponen, 2008; Teng, 2007).

Based on case studies, Lerner and Merges (1998) developed a list of control rights that commonly appear in contracts and analyzed how they were included ex ante in each agreement. Of the five most commonly used control rights categories identified by Lerner and Merges (1998), "determination of alliance scope" and "control of intellectual property" are the most relevant to our research question. Thus, determining which activities to include in an R&D alliance — or the alliance scope — involves decisions such as whether or not to restrict joint activity to precompetitive R&D (Oxley & Sampson, 2004). Alliance scope depends on activities that are unrelated to the alliance (Khanna, Gulati & Nohria, 1998), and is largely within the partner firm's control (Khanna, 1998). Alliance scope is contingent on both the source of the new information created and the targeted markets for the new products or services (Khanna, 1998), and is closely linked to alliance boundaries (Ariño & de la Torre, 1998). It is suggested that firms that neglect to define the control rights under the alliance scope during the negotiation phase will choose the sole option for any patentable invention that results (Slowinski & Sagal, 2006).

The second cluster of specific control rights concerns the control of intellectual property. Because many biotechnology firms consider patents and the associated scientific knowledge their most important assets, it is not surprising that they generally focus on these in the alliance negotiation (Lerner & Merges, 1998). The most critical right is the ownership and possible sharing of projectgenerated patents.

There are several explanations for how the allocation of control rights can influence joint patenting activity. Biotechnology R&D alliances are often created in strategic factor markets, where they provide specialized knowledge and research skills, whereas pharmaceutical firms contribute funding, the product development approval process, and marketing capabilities (Abegbesan & Higgins, 2010). In this case, the more control rights allocated to the biotechnology firm, the more ownership it will have of the foreground knowledge, and the greater the benefits it will receive from the collaboration (Lerner & Merges, 1998; Panico, 2011). In other words, the pharmaceutical company retains ownership of the alliance output when it retains the ex-ante control rights.

To protect foreground knowledge, the biotechnology company may either file a patent alone or jointly with a partner. The high costs of patents, which biotechnology companies cannot afford on their own, may lead them to patent the output of the alliance jointly with a partner. An alliance would therefore more probably lead to a joint patent when the ex-ante control rights are allocated to the biotechnology firm and not the pharmaceutical firm.

In some cases, R&D alliances are formed between two biotechnology firms that are facing financial challenges. These alliances contain horizontal elements, because both firms often contribute patents or informal elements to the agreement. According to Aghion and Bolton (1992), co-ownership is suboptimal compared to unilateral ownership, given that co-ownership exacerbates ex-post hold-up problems. Sharing intellectual property rights through a joint patent may increase the risk of opportunism, however, and it raises important issues of joint IP management, such as patent litigation control or payment for the filed patent. Another potential complication is the legal status of the joint patent. In the US, “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” (.35 U.S.C. §262). The consequences of co-inventor status are therefore significant. As Merges and Locke (1990: 587) point out, “Co-owners are at the mercy of one another in the absence of special agreements that protect against problems associated with the [above] general rules.” To avoid this complication as well as potential ex-post opportunism, Teng (2007) suggests drawing up an explicit agreement. Previous studies on contract complexity also show that the number of specific control rights is negatively associated with perceived ex-post opportunism (Parkhe, 1993; Deeds & Hill, 1998). Analyzing the relative effectiveness of the different groups of control rights in buyer–supplier relationships, Kloyer (2011) finds that the assignment of enforceable intellectual property rights (IPR) effectively motivates suppliers to refrain from opportunism. In this case, there is every reason to believe that the contractual elements, and especially control rights, act as control mechanisms to reduce concerns caused by joint ownership.

Taken together, the above arguments suggest that a large number of specific control rights allocated to the biotechnology firm would be positively associated with joint patent activity, either because the biotechnology firm cannot patent the innovation alone, or because shared ownership is subject to a greater threat of opportunistic behavior.

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H 1: The number of specific control rights allocated to the biotechnology firm is positively related to joint patenting activity.

The resource-based view of allocation of property rights

Ownership is defined as residual control rights to assets (Grossman & Hart, 1986). As Rugman and Verbeke (2002) note, the central premise of the RBV is that "unique resources and capabilities represent the main determinants of corporate performance relative to rival firms" (2002: 176). These resources are unique because they are specialized (Amit & Schoemaker, 1993), and, depending on their complexity, they are difficult to transfer (Kogut & Zander, 1992). Windsperger (2009) shows that the nature of assets influences the allocation of control rights: the partners' intangible assets positively influence the tendency toward a higher proportion of residual control rights.

Technological Specialization and Joint Patenting Activity

Amit and Schoemaker (1993) report that "strategic assets by their very nature are specialized" (1993: 39). In the high-tech sector, specialized technological assets are related to the firms' core competencies and strategic assets (Duysters & Hagedoorn, 2000), and they can differ between companies. Specialization, or more precisely "specificity," is common to both transaction cost theory (TCT) (the "transaction-specific asset") and the resource-based view (RBV) (the "firm-specific asset"). Assets that are specific to a particular transaction refer to "the degree to which the assets used can be redeployed to alternative uses and by alternative users without sacrifice of productive value" (Williamson, 1991: 281). Transaction-specific assets have substantial value-creation properties, and at the same time they influence transaction costs (Riordan & Williamson, 1985), given the opportunistic behavior they can generate. Firm-specific assets are described as imperfectly mobile: that is, they are "tradable but more valuable within the firm that currently employs them that they would be in other employ" (Peteraf, 1993: 183). Firm-specific resources may be gainfully applied to multiple uses in various product markets, through internal or external transactions and in combination with various complementary assets (Teece, 1986). These two kinds of specific assets are intertwined (Madhok & Talman, 1998). The value associated with the transaction-specific resource is tied to other idiosyncratic, firm-specific resources. The more specialized the firm, the more its resources are inaccessible to other firms, and the more attractive they become to the alliance partner (Eisenhardt & Schoonoven, 1996). In addition, the more specialized the firm's technology, the more that firm will invest specific assets in the relationship alliance. The specificity is the keystone of the alliance: it increases the relative value of the firm's transaction-specific assets, and in turn, the partner's dependence on the relationship (Nooteboom, 1996). However, the transaction-specific assets may increase in value only if the specialized firm is willing to forego some returns on its investment, which is unlikely for a rational rent-seeking firm (Madhok, 1996). Kim and Mahoney (2002) suggest that specific resources can be viewed in terms of property rights. Thus, "the more valuable the resources, the more incentives there are to make property rights of resources more precise and the more precisely delineated the property rights of resources, the more valuable resources become" (2002: 235). Consequently, they argue that the process of making property rights more precise can be another way of looking at the value creation process. In fact, the management of resources must take into account the transformation from an ex-ante competitive situation to an ex-post joint situation, maximizing the quasi-rent. Consequently, the more specialized the firm, the more likely it is to have problems sharing its technology with its partner, and the less likely that the output of the transaction will be shared and jointly owned.

The above discussion leads to the second hypothesis. According to the RBV, there should be a negative relationship between the degree of specialization and joint patenting.

H 2a: There is a negative relationship between the degree of firm specialization and involvement in joint patenting.

Several authors show that alliances are more likely to succeed when the partners possess complementary resources (e.g., Chung, Sigh & Lee, 2000; Hamel, Doz & Prahalad, 1989). For instance, Hamel et al. (1989) suggest that mutual gains are possible when the partners can complement each other's weaknesses. Complementarity ensures that the two partners bring different but valuable resources to the relationship (Kale, Singh & Perlmutter, 2000). The combination of the complementary resources results in the creation of a surplus. Nevertheless, according to Adegbesan (2009), the degree of complementarity varies, which leads to variations in the amount of surplus that can be created. Because this surplus does not depend on the resources of one or the other partner, but rather on their combination, the splitting of the surplus between the partners is indeterminate ex ante (Adegbesan & Higgins, 2010). Adegbesan and Higgins (2010) show that strong complementarity is a driver of intra-alliance value division, so that the division of property can favor one or the other partner. In other words, when the biotechnology firm has substantially invested in specialized resources, the greater the degree of complementarity, the more asymmetric the division of the surplus. Similarly, Delerue (2011) shows that high overlap in technological expertise, and therefore low complementarity (Mowery, Oxley & Silverman, 1998), appears to favor joint patenting. When the alliance partners have similar technological expertise and high potential absorptive capacity, it is easier to share knowledge in order to achieve a joint project (Sampson, 2007). Teng (2007) also suggests that joint ownership is preferable because it provides guaranteed access to IP (sometimes through cross-licensing) and reduces the risk of patent interference and patent blocking. That is, it prevents rivals from patenting related inventions.

Taken together, these arguments suggest that when the degree of complementarity is high, it would be more risky for a specialized firm to share intellectual property rights through joint patenting. Consequently,

H 2b: Resource complementarity strengthens the negative effect of the degree of firm specialization on involvement in joint patenting.

Technological Complexity and Joint Patenting Activity

Complexity increases the costs of transferring knowledge across organizational boundaries, as well as the degree to which that knowledge resists identification (Williamson, 1985; Zander & Kogut, 1995). This attribute of knowledge has been associated with the height of imitation barriers (Dierickx & Cool, 1989; McEvily & Chakravarthy, 2002). Accordingly, MacMillan, McCaffery, and Van

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Wijk (1985) argue that competitors find it harder to imitate products when a complex set of skills is needed to develop them. Complexity entails "causal ambiguity" and "uncertain imitability" (Lippman & Rumelt, 1982; Reed & Liparini, 1990). It also has implications for the enforceability of intellectual property protection (Cassiman & Veugelers, 2002; Cohen, Nelson & Walsh, 2000). Complexity can be defined in many ways. For instance, complexity "increases the difficulty of comprehending how a system (i.e., an organization, organism, device) functions or produces some outcome" (McEvily & Chakravarthy, 2002; 289). Alternatively, an item is complex if it consists of many elements with extensive interaction across elements (Simon, 1962). Complex technologies, in particular, are systemic, have multiple interactions, and are nondecomposable into subsystems (Singh, 1997) so as to maintain optimal performance. Technological complexity increases the costs of knowledge transfer across organizational boundaries, as well as the degree to which it resists identification (Zander & Kogut, 1995). Consequently, the development of highly complex technologies requires a complex structure (Roberts, 1990), along with closer integration and greater commitment. This view is shared by Glynn, Kazanjian, and Drazin (2010), who show that complex product development requires high structural interteam interdependence. Gulati and Sytch (2007) also show that higher component complexity leads to greater mutual dependence due to the need for close coordination. With greater coordination, there is less reluctance to hold the informal and open idea exchanges between partners that are necessary for joint patenting (Slowinski & Sagal, 2006).

Moreover, the extraction and replication of a complex set of interrelated capabilities and knowledge becomes problematic when firms collaborate on R&D projects. Complexity leads to problems in assessing and comparing each party's contributions, gains, and competencies in the collaboration process. The new knowledge resulting from R&D collaboration generates causal ambiguity, and the complexity prevents partners from dividing the inventions between them (Hagedoorn, 2003). Consequently, when technologies are complex, ownership is shared, along with the rents earned on innovations.

To conclude, either it is much too difficult to transfer resources during the alliance process and the alliance is therefore bound to fail, or the partner firms manage to develop a complex structure to facilitate the transfer of complex resources and knowledge, which leads to sharing the alliance output through joint patenting. Taken together, the above arguments suggest that complexity is more likely to involve joint patenting activity because: 1) the economic rent it may generate is more efficient for indivisible resources; 2) it is difficult for the partners to divide the IP; and 3) the joint organization it requires involves close relations.

H 3: The degree of technological complexity will be positively related to joint patenting activity.

Method

It has been shown that ex-ante control rights are endogenous and self-selected (Ryall & Sampson, 2009; Lumineau & Malhotra, 2011; Lerner & Mergers, 1998). The empirical analyses therefore first examine the determinants of ex-ante control rights allocation, and second, some key factors for joint patenting activity in the biotechnology sector.

Data Collection and Sample

Our sampling unit is a set of early-stage R&D agreements (pre-clinical and phase I, II, and III clinical trials) contracted by small- and medium-sized U.S. biotechnology firms. We excluded joint ventures because they often provide joint ownership and control over the use and fruits of assets (Kogut, 1988). We selected this industry because most biotechnology firms, lacking the means for innovation, enter into multiple R&D alliances with drug firms, universities, public institutes, and other biotechnology firms (Filson & Morales, 2006). The industry is also characterized by rapid technological development and a high degree of intellectual property rights protection. Moreover, the probability of co-assignment and co-assignment growth varies across technologies. For example, chemical firms almost never co-assign their patents (0.08%), whereas about 8% of biotechnology patents are co-assigned (Khoury & Pleggenkuhle-Miles, 2011). We excluded biotechnology firms that are wholly-owned subsidiaries of pharmaceutical companies, but we included those with minority investments by large organizations. Our objective was to ensure there were no ownership linkages between joint patenting firms. We identified firms who entered into contractual R&D alliances according to the BioScan database.

Data were collected from various databases (BioScan, Compustat, USPTO) and a questionnaire survey. The questionnaire was sent to managers of the 634 US biotechnology companies that met our criteria (independent biotechnology SMEs that had contractual R&D alliances). Data were collected at the beginning of 2009. The managers' names were listed either in the BioScan database or on the firms' websites.

Assuming that senior managers have the best vantage point for viewing the entire organizational system, especially in small firms, a single key informant was targeted, as in similar studies (e.g., Powell, 1992). Surveys were addressed to and completed by either the owner or business manager of each firm. A common method variance bias can result from collecting dependent and independent variables from the same respondent. We tried to avoid consistency artifacts by placing more subjective questionnaire items before objective ones (Salancik & Pfeffer, 1977). Moreover, most of the construct items were separated and mixed so that the respondents would be unable to readily detect which items affected which factors. It is therefore reasonable to assume that common method variance bias was minimized.

The main problem with mailed surveys is the potential bias resulting from low response rates (Fox, Robinson & Boardley, 1998). We tested for non-response bias by comparing respondents and non-respondents in terms of firm size. A one-way analysis of variance (ANOVA) for firm size across respondents yielded an insignificant F-value of 0.55 (n.s.).

In five cases, respondents answered more than one questionnaire. Consequently, observations were selected such that group linkage may exist. This can lead to non-independence of observations. Non-independence due to groups is conventionally measured by the intraclass correlation (Kenny & Jugg, 1996). To test for non-independence due to groups, a one-way ANOVA was conducted on the data with groups as the single factor. Before computing a one-way ANOVA, a Kolmogorov-Smirnov test was applied to determine the normality of the variables. All variables are normally distributed. No differences were found for the other variables. We received responses from 97 firms, for

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which 116 questionnaires were completed, yielding a 15.2% response rate. The mean number of employees at the firms is 115. Thirty-two percent of the agreements led to a joint patent, and most of these patents are filed with a large US firm (78%). Fifty-one percent of the R&D agreements are contracted with a large US firm. The average age of the alliance is 4.27 years.

Measures

The data used to test the hypotheses were collected in two ways: from a database and from a survey questionnaire. To ensure the reliability and discriminant validity of the constructs, most questionnaire items have been used in prior research.

Dependent variables

Our first dependent variable is specific control rights. The measures for specific control rights include 12 of the 25 key control rights defined by Lerner and Merges (1998). We focus on two control rights categories: "determination of alliance scope" and "control of intellectual property" (see Lerner & Merges, 1998: 143). Respondents were asked whether their organization has or has not included such control rights in the alliance contract. The variables are binary, with a value of one indicating that the particular right was allocated to a biotechnology firm, and zero otherwise. Table 1 summarizes the frequency with which these 12 control rights appear in the contract, representing their relative importance. We consider that high frequency means that the control right is generally included in the contract and therefore constitutes a basic clause. In order to distinguish particular specific control rights (those that appear less frequently) from basic specific control rights, we assigned each a corresponding value ("weight" column in Table 1). Thus, the most frequently included control right in a contract takes the value 1 and the least frequently included takes the value 12. We applied Parkhe's (1993) formula to determine an index of specific control rights, computed as follows:

$$\text{Weighted specific control rights} = \frac{1}{78}\sum_{i=1}^{12} CR_i$$

where CRi equals i if the ith control right is included in the contract, and zero otherwise. The summation term ranges from 0 to 78, and division by 78 yields a measure ranging from zero to one.

Table 1. Percentage of Specific Control Rights Allocation to the Biotechnology Firm

Frequency of usea	%	Weight
Alliance scope		
Right to extend the term of the alliance	22.4	8
Right to sublicense	62.3	2
Reserve the right to shelve projects	38.3	4
Right to terminate particular projects	20.1	10
Right to terminate the alliance without cause	17.8	11
Right to license technology after termination of the alliance	54.6	3
Control of intellectual property		
Control of the conduct of patent litigation	21.4	9
Right to delay publication	76.9	1
Partial ownership of patents	29.6	6
Ownership of core technology	17.7	12
Right to know-how transfer	35.2	5
Ownership of patent	25.2	7

N = 116

The control right most frequently allocated to the biotechnology firm is the “right to delay publication” (76.9%), followed by the “right to sublicense” (62.3%). The least frequently included control rights are: the “right to terminate the alliance without cause” (17.8%), the “right to terminate particular projects” (20.1%), and those that mainly concern patent ownership (25.2%). Specific control rights frequency is closely related to the order of contractual provision stringency proposed by Parkhe (1993). For instance, “termination of agreement” and “lawsuit provision” are considered stringent contractual safeguards.

Dimensionality of Specific Control Rights. The mean number of control rights included in the sampled alliance contracts is 5.3. Twenty-five percent of the firms have at least four types of specific control rights, and 25% have more than seven. This distribution highlights the heterogeneity of the number of specific control rights. In order to qualitatively investigate the impact of specific control rights, we determined the dimensionality of specific control rights. Given the categorical nature of our data set, we used a tetrachoric correlation matrix followed by a principal component factor analysis to examine the dimensionality of specific control rights (see Reuer & Ariño, 2007). Table 2 presents the estimated tetrachoric correlations among specific control rights, and Table 3 presents the factor analysis results. The factor analysis yielded a three-factor solution (eigenvalue exceeded one), with factor 1 being the alliance scope, factor 2 the control mechanisms, and factor 3 ownership. Taken together, the factors explained over 73% of the data variance. The conceptual dimension, or "control of intellectual property," yielded two factors that distinguish "control of intellectual property" from "division of IP ownership." Nevertheless, the low communality for "partial ownership of patent" suggests that this factor model does not provide a good fit for this specific control right. Moreover, "partial ownership of patent" loads high on factor 2 and factor 3. This item was dropped from the final factor analysis, as presented in Table 3.

Table 2. Tetrachoric Correlations among Specific Control Rights

		1	2	3	4	5	6	7	8	9	10	11
1	Right to extend the term of the alliance											
2	Right to sublicense	.34**										
3	Reserve the right to shelve projects	.20*	.28*									
4	Right to terminate particular projects	.28*	.32*	.46**								
5	Right to terminate the alliance without cause	.33**	.33**	.45**	.29*							
6	Right to license technology after termination of the alliance	.21*	.24*	.62**	.34*	.36**						
7	Control of the conduct of patent litigation	.11	.28*	.39*	.21*	.25*	.39**					
8	Right to delay publication	.26*	.03	.56**	.54**	.49**	.72**	.37**				
9	Partial ownership of patents	.51*	.53**	.70**	.32*	.32*	.59**	.78**	.24*			
10	Ownership of core technology	.07	.20	.38**	.23	.19	.11	.22*	.13	.26*		
11	Right to know-how transfer	51**	.10	.45**	.19	.57**	.26*	.27*	.38**	.12	.11	
12	Ownership of patent	.28*	.04	.33**	.29*	53**	.35**	.47**	.35**	.04	32**	.45**

Table 3. Factor Analysis of Specific Control Rights[a]

Specific control rights	**Factor 1 Alliance scope**	**Factor 2 Control**	**Factor 3 Ownership**
Right to extend the term of the alliance	**.86**	.10	.09
Right to sublicense	**.89**	.09	.07
Reserve the right to shelve projects	**.71**	.12	.12
Right to terminate particular projects	**.70**	.11	.23
Right to terminate the alliance without cause	**.81**	.06	.35
Right to license technology after termination of the alliance	**.85**	.12	.08
Control of the conduct of patent litigation	.10	**.82**	-.38
Right to delay publication	.29	**.71**	.13
Ownership of core technology	.01	.12	**.79**
Right to know-how transfer	.03	**.73**	.21
Ownership of patent	-.023	.27	**.79**
Eigenvalue	3.70	1.98	1.09
% of variance	49.94	19.98	11.20

[a]. *without "partial ownership"*

Our second dependent variable, joint patent, represents whether or not the collaborative process resulted in at least one joint patent. A patent is considered collaborative when it is jointly owned with an economic actor (e.g., another firm, an institute, or a university). This variable was binary coded (Yes = 1, No = 0).

Independent Variables

Our first set of covariates identified the antecedents of specific control rights. Previous studies suggest that the ex-ante allocation of control rights may reflect the bargaining power of the partners (Adegbesan & Higgins, 2010; Aghion & Tirole, 1994; Leiponen, 2008). Hence, our covariate is bargaining power, which is proxied by a set of firm characteristics that include firm size, R&D expenditures, new product development, and number of patents. These variables are also included as control variables in explaining joint patenting activity. Firm size is measured by the logarithm of the number of employees, obtained from the BioScan database. R&D expenditures is measured by the

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logarithm of the mean of R&D expenditures over the five years before the alliance formation. This measure is derived from the Compustat database. R&D expenditures was used by Lerner and Merges (1998) as an indicator of the firm's financial position. New product development is taken from BioScan's description of each biotechnology firm's new product development activities. Using pre-alliance formation data, we coded all products in preclinical trials, clinical trial phases I–III, and the FDA approval process as new product development. We also controlled for a firm's innovativeness by including the number of patents it had obtained pre-alliance. Patents are also considered a signal to potential partners, as they may increase the firm's bargaining power. We used US patent office data because the US market would be the most relevant for US biotechnology firms.

Our first main independent variable is technological specialization. According to Rothaermel (2002), the degree of technological specialization is captured by the number of subject applications by each firm according to the BioScan database. In biotechnology, technology platforms and trajectories are typically based on a number of different subfields (Rothaermel, 2002). Biotechnology is used to work with existing products in new ways, identify new product opportunities (as in drug discovery), and produce new products that could not be commercially produced previously. Seven biotechnology technologies and methods are employed in a range of biotechnology fields: DNA/RNA, proteins and other molecules, cell and tissue culture and engineering, process biotechnology techniques, gene and RNA vectors, bioinformatics, and nano-biotechnology (OECD, 2005). These biotechnology fields can be divided into subfields. For example, the category cell and tissue culture includes five subcategories: cell line development, tissue engineering, cellular fusion, immune stimulants, and embryo manipulation. In our study, the number of biotechnology subfields in which a firm participates is used as a proxy for the degree of specialization: the fewer the subfields, the less diverse a firm's technological resources. Two biotechnology experts with doctoral degrees were employed to ensure accurate classification. One owned a biotechnology firm and the other worked for another biotechnology firm. Twenty percent of the firms operated in ten or more biotechnology subfields, 48% focused on fewer than five subfields, and 31% operated in from five to ten subfields. We counted 37 subfields in our sample. As an indicator for technological specialization, we used the ratio of the total number of biotechnology subfields to the number of firms' biotechnology subfields.

Our second independent variable is complexity. We constructed a measure of complexity using three items on a 5-point Likert subjective scale adapted from Simonin (1999) and based on the definition of complexity proposed by Zander and Kogut (1995) (see Table 4). This measure was chosen over the objective measure of technological complexity, which uses the number of patent subclasses (see Fleming & Sorenson, 2001). Objective measurement takes into account publishable intellectual property only, whereas complexity is an inherent characteristic of high tacit knowledge (Simonin, 1999), which is not always patentable.

Control Variables

We sought to develop a model of the factors that potentially influence firms' joint ownership activity in R&D alliances, but we also wanted to control for relevant contingencies that may influence the firms' decisions. We therefore introduced several control variables (Table 4).

Table 4. Description of Variables

Variables	Survey items	Cronbach's α
Complexity	1. Few employees have sufficient breadth or depth of knowledge to fully grasp the extent of the overall innovation. 2. Our innovations are generally based on several scientific disciplines. 3. Our technology and⁄or process know-how is the product of many interdependent techniques, routines, individuals, and resources.	.79
Complementarity a	1. There is high complementarity between the resources and capabilities of the two partners. 2. There is high similarity or overlap between the core capabilities of each partner (reversed). 3. This alliance relationship would not be possible without our partner's resources and competencies. 4. Our partner and we are mutually dependent on each other since we contribute different resources and competencies.	.82
Interorganizational Trust	1. Our partner has always been even-handed in its negotiations with our company. 2. Our partner may use opportunities that arise to profit at our expense (reversed). 3. Based on past experience, we cannot rely on our partner with complete confidence to keep the promises it made to us (reversed). 4. We are hesitant to transact with our partner when specifications are vague (reversed). 5. We trust this partner to treat us fairly. 6. We trust that the confidential and/or proprietary information that we share with our partner will be kept strictly confidential.	.91
Alliance performance	1. Many alliances result in "spillover" effects for their parent firms. For example, positive spillover effects may occur when know-how that is gained from alliance activities can be applied profitably to non-alliance operations as well. Negative spillover effects may occur due to competition between the alliance and other parent firm operations, such as when geographic markets overlap. In the present alliance, the net spillover effects for your firm are (1 = strongly negative, 5 = strongly positive). 2. Using the most significant indicator of profitability in the context of this alliance (such as return on investment, return on sales, or return equity), the profitability of your alliance relative to the profitability of the industry in which the alliance belongs would be (1= far lower, 5 = far greater). 3. In your overall assessment, how has the alliance performed compared to your expectations? (1 = very poorly, 5 = very well).	.90

[a] *Items (except for Alliance performance items) are measured on a 5-point Likert scale with options ranging from 1 = "Strongly disagree" to 5 = "Strongly agree."*

Complementarity is measured using four survey items inspired by Kale et al. (2000). Principal component analysis revealed that all items overwhelmingly loaded on a single factor (Cronbach's = .82). Joint R&D projects can take various forms, depending on whether the partners are divided into more or less independent spheres or whether they fully integrate each aspect of the project (Gerwin & Ferris, 2004). In other words, some firms may prefer to collaborate on complementary R&D (e.g., vertical cooperation, suppliers–buyers), while others reap private benefits from horizontal cooperation. Complementarity captures the R&D project design in that the more complementary the resources, the more the R&D alliance will be divided into independent spheres. Complementarity may therefore affect the likelihood of joint IP ownership.

Interorganizational trust is based on closed interactions and relationships that develop over time (Gulati, 1995). According to Slowinski and Sagal, (2006), with joint patenting there is less reluctance to hold informal and open idea exchanges between partners. We therefore introduced interorganizational trust to capture the atmosphere in the alliance relationship. Interorganizational trust is measured using a six-item scale similar to those used in the literature (Zaheer, et al., 1998; Gulati & Sytch, 2007). Principal component analysis revealed that all items overwhelmingly loaded on a single factor. The six items were aggregated into an overall measure of interorganizational trust, with 0.91 reliability.

Alliance performance was introduced as a control variable, given that a joint patent is a potential indicator of alliance performance (Rocha, 1999). Alliance performance is measured using a three-item scale adapted from Parkhe (1993). Principal component analysis revealed that the three items overwhelmingly loaded on a single factor. The three items were aggregated into an overall measure of alliance performance, with 0.90 reliability.

Joint patent experience was measured by the number of patents the firm has jointly filed in the past, according to the USPTO database. Certain organizational factors, such as the firm's experience and expertise in managing IP, may explain IP ownership decisions (Teng, 2007). The number of a firm's joint patents proxies for the firm's experience, and as a control variable, allows us to distinguish between firms with high and low experience.

Table 5 presents the summary statistics and correlation coefficients for the variables. No correlation is sufficiently large to pose estimation problems.

Table 5. Descriptive Statistics and Correlation Matrix

		Mean	SD	1	2	3	3	4	5	6	7	8	9	10	11
1	Joint patent b	.32	.04												
2	Size	4.30	.09	.18*											
3	No. of patents	18.86	4.36	.24**	.22**										
4	R&D expenditures	1.11	.05	.22**	.45**	.21*	.21*								
5	New product development	5.35	.38	.27**	.21*	.17*	.17*	.31**							
6	JP experience	1.81	.49	.37**	.22**	.49**	.49**	.19*	.38**						
7	Complementarity	13.51	.35	.02	.13	-.04	-.04	.01	.07	.05					
8	Interorganizational trust	22.4	.36	.01	-.04	-.16	-.16	.04	-.04	-.10	.19*				
9	Alliance performance	10.57	.25	.27**	.13	.10	.10	.15	.0169	.04	-.03	.23*			
10	Technological specificity	.18	.02	-.31*	-.07	-.14	-.14	-.11	-.13	-.10	-.05	-.11	-.11		
11	Complexity	9.61	.24	.46**	.17*	.26**	.26**	.20*	.06	.19*	-.02	.08	.08	-.18*	
12	Weighted specific control rights	23.81	1.73	.71**	.23**	.31*	.31*	.38*	.18*	.31**	-.03	.07	.26**	.26**	.43**

[a] Pearson correlations are provided for all continuous variables and Spearman correlations are provided for the dichotomous variable.
** p < 05.*
*** p < .01.*
**** p < .001.*
N=116.

Analysis

We begin by assessing the endogeneity of specific control rights. Our first equation is as follows:

Specific control rightsi = $\alpha_0 + \alpha_1$ * *Firm size* + α_2 * *Patents* + α_3 * *R&D expenditure* + α_4 * *New product development* + α_5 * *Joint patent experience* + α_6 * *Complementarity* + α_7 * *Technological specialization* + α_8 * *Complexity* + ε_{i1} (Equation 1)
where ε_{i1} is a random error term.

Given that technological specialization, technological complexity, and complementarity are known at the outset of alliance formation, these variables were also introduced into this equation.

In the second stage of our model, we used a probit model to examine the effect of technological specialization, complexity, alliance attributes, and specific control rights (estimated in the first stage) on joint patent activity.

If the variable specific control rights is endogenous, it is hence correlated with the error term in the second equation. We first estimated the determinant of specific control rights and then tested for the endogeneity of specific control rights in Equation 2 by introducing the residuals as additional explanatory variables. The residuals were statistically significant for weighted specific control rights and the control dimension, indicating endogeneity ($F = 11.40$, $p < 001$ for weighted specific control rights and $F= 5.61$, $p < .05$ for the control dimension) (Davidson & MacKinnon. 1993). Surprisingly, the null hypothesis of exogeneity is accepted for the alliance scope and ownership dimensions.

Our second-stage equation is as follows:

JPij : $\beta_0 + \beta_1$ * *Firm size* + β_2 * *Patents* + β_3 * *R&D expenditure* + β_4 * *New product development* + β_5 * *Joint patent experience* + β_6 * *Complementarity* + β_7 * *Interorganizational trust* + β_8 * *Alliance performance* + β_9 * *Technological specialization* + β_{10} * *Technological complexity* + β_{11} * *Specific control rights* + ε_{2i} (Equation 2).

Results

We first estimated the determinants of specific control rights. Table 6 presents the set of models used to assess specific control rights. The results for Equation 1 are shown for four different dependent variables: Weighted control rights, Alliance scope, Control, and Ownership dimensions. Model 1 (Weighted control rights) shows an R^2 of .52, Model 2 (Alliance scope) an R2 of .11, Model 3 (Control) an R2 of .56, and Model 4 (Ownership) an R2 of .63. The estimation model is an ordinary least squares (OLS) model. The coefficient for R&D expenditures is significant in Model 1 ($\beta = .07$, $p < .01$), Model 3 ($\beta = .08$, $p < .001$), and Model 4 ($\beta = .09$, $p < .01$). Bargaining power measured by R&D expenditures significantly explains Weighted specific control rights, Control, and Ownership dimensions. Joint patenting (JP) experience is significant in all four models, showing that joint patenting experience influences contract content and complexity. Complementarity is significant in Model 2 only (Alliance scope) ($\beta = .19$, $p < .05$). In fact, Oxley and Sampson (2004) argue that the scope of alliance activities depends on the organization of joint R&D. Our technological specialization proxy is significant in Model 1 (Weighted specific control rights, $\beta = 3.49$, $p < .001$), Model 2 (Alliance scope, $\beta = .23$, $p < .10$), Model 3 (Control, $\beta = .04$, $p < .05$), and

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Model 4 (Ownership, $\beta = .51$, $p < .05$). Complexity is also significant in all four models: Model 1 (Weighted specific control rights, $\beta = 1.43$, $p < .001$), Model 2 (Alliance scope, $\beta = 1.67$, $p < .10$), Model 3 (Control, $\beta = .05$, $p < .10$), and Model 4 (Ownership, $\beta = .68$, $p < .10$). Note that both technological specialization and complexity—our main explanatory variables—are related to specific control rights. This suggests that firms' resource attributes are important in explaining the allocation of ex-ante control rights. Firm size has often been used as a proxy for bargaining power. Nevertheless, as shown in Table 6, the coefficient of firm size is positive but not significant for all models. Leiponen (2008) also finds an unexpected marginally positive effect of firm size on the allocation of control rights to clients. Our results suggest that firm size is not a relevant factor for explaining the allocation of control rights to the biotechnology firm and JP in our sample. The number of patents the firm has previously filed is positive but significant only in Model 4 (ownership, $\beta = .01$, $p < .01$). This means that patenting may influence only specific control rights regarding ownership. New product development is positive but significant only in Model 3 (control, $\beta = .10$, $p < .05$). None of the other variables are significant. These results suggest that the dimensions of bargaining power may differently influence the allocation of specific control rights according to their objective.

Table 6 presents the results for models 5 to 11 from our probit analysis of joint patenting activity. Model 5 is a baseline model, with a pseudo-R2 of .26. None of the explanatory variables in the first equation of the joint patent equation (Equation 2) is significant. Model 5 offers no significant improvement over Model 6, which does not introduce bargaining power variables. Consequently, models 7 to 11 do not introduce bargaining power variables. Model 7, which includes a technological specialization proxy and the interaction term (technological specialization * complementarity) yields a pseudo- R2 of .35. Prior to creating the interaction terms, we centralized all variables to improve the interpretability and reduce the possibility of multicollinearity (Aiken & West, 1991). Model 8, which includes complexity, yields a pseudo-R^2 of .59. Models 9, 10, and 11 are probit models with weighted specific control rights (Models 9 and 10) and the control dimension as endogenous repressors (Model 11).

The variable predicted specific control rights (P_Weighted Specific control rights) obtains a positive and statistically significant coefficient in the probit endogenous model. P-weighted specific control rights as a proxy of contract complexity has a positive effect on joint patent activity ($\beta = .09$, $p < .001$). Qualitatively, control rights regarding alliance scope ($\beta = .19$, $p < .10$) and control ($\beta = 4.48$, $p < .01$) have a positive effect on joint patenting activity. The effect of ownership is negative but not significant. This result is particularly interesting, as it suggests that property rights allocated ex ante to the biotech firm would not explain the presence or otherwise of joint patenting. The probability that the partners would joint patent the innovation would be much higher if the biotechnology firm retained the right to define the alliance scope and control rights relative to IP control. Taken together, these results provide support for Hypothesis 1.

The coefficient of our technological specialization proxy is negative and significant ($\beta = -9.14$, $p < .001$) in Model 7, supporting Hypothesis 2a. However, this coefficient becomes insignificant when "specific control rights" are introduced into the model (Model 10 and Model 11). According to Baron and Kenny (1986), "a variable functions as a mediator (a) when the independent variable has a significant impact on the mediator, (b) when the mediator has a significant impact on the dependent variable and (c) when the two effects are controlled, a previously significant relation between the independent variable and the dependent variable is no longer significant" (1986: 1176). These three conditions are satisfied. This result therefore suggests that specific control rights, and consequently contracts, may be mediator variables between technological specialization and joint patenting activity, validating our second hypothesis only partially. Technological specialization has only an indirect effect on joint patenting activity.

In conclusion, our results show that the variable specific control rights has a positive effect on joint patenting and mediates the negative effect of technological specialization on joint patenting activity. These findings suggest that 1) the overall effect of technological specialization on joint patenting activity is negative; 2) this negative effect is indirect, acting through the allocation of ex-ante control rights, particularly control rights related to alliance scope and IP control; and 3) according to the allocation of specific control rights (i.e., contract content and complexity), this negative effect disappears when contracts are complex (the number of control rights allocated to the biotechnology firm increases particularly for those related to alliance scope and IP control).

Hypothesis 2b suggests that the degree of resource complementarity strengthens the negative effect of the degree of firm specialization on joint patenting activity. The results show that the interaction term between technological specialization and complementarity is significantly and negatively ($\beta = .-1.51$, $p < .001$) associated with joint patenting. Hypothesis 2b is therefore supported.

The coefficient of complexity is statistically significant in all models (Model 8, $\beta = .47$, $p < .001$; Model 10, $\beta = .27$, $p < .01$; Model 11, $\beta = 3.13$, $p < .05$). The estimation results therefore strongly support Hypothesis 3.

The effect of control variables on joint patenting. Our results show that when firms have prior experience in filing patents jointly, the probability is higher that they will share IP ownership. The coefficient of general joint ownership experience is positive and significant in all the models.

Not surprisingly, alliance performance is positively related to joint patenting activity. The positive effect of interorganizational trust is significant only when specific control rights are introduced into the model. This may be explained by the correlation between specific control rights and interorganizational trust. Complementarity is not significant.

Table 6. Estimation results from multivariate analyses [a]

	OLS				**Probit model**				**Probit endogeneous model**		
	Weighted	**Scope**	**Control**	**Ownership**				**Joint patent [b]**			
	Model 11	**Model 12**	**Model 13**	**Model 14**	**Model 15**	**Model 16**	**Model 17**	**Model 18**	**Model 19**	**Model 20**	**Model 21**
Size	.40 (1.17)	.30 (.36)	.00 (.01)	.04 (.14)	.08 (.14)						
No. of Patents	.03 (.03)	.02 (.09)	.01 (.01)	.01** (.00)	.00 (.00)						
R&D expenditures	.07** (.02)	.60 (.66)	.08*** (.02)	.09** (.09)	.05 (.27)						
New product development	.20 (.29)	.04 (.07)	.10* (.06)	.00 (.03)	.04 (.03)						
JP experience	.44† (.24)	-.01† (.01)	.01† (.01)	.07* (.03)	.25** (.07)	.26*** (.06)	.35*** (.08)	.31*** (.08)	.085† (.04)	.11† (.06)	.21* (.08)
Complementarity	-.07 (.28)	.19* (.09)	-.00 (.00)	-.39 (.03)	.00 (.03)	.01 (.03)	.01 (.04)	.01 (.04)	.05 (.04)	.05 (.04)	.02 (.05)
Interorganizational trust					-.01 (.03)	.01 (.03)	.04 (.07)	.09 (.09)	.09* (.04)	.10† (.04)	.14* (.17)
Alliance performance					.12** (.05)	.14** (.05)	.14** (.05)	.18** (.07)	.12** (.05)	.12* (.06)	.17* (.06)
Technological specialization	3.49*** (.40)	.23† (.09)	.04* (.00)	.51* (.01)			-9.14*** (1.90)		.09*** (.01)	-2.87 (1.98)	-.18 (.09)
Technological specialization * Complementarity							-1.51** (.55)				
Complexity	1.43† (.45)	1.67† (.68)	.05† (.03)	.68† (.26)				.47*** (.08)		.27** (.08)	.31* (.08)
P_Weighted specific control rights										.09** (.01)	
Alliance scope											.19† (.17)
P_Control											4.48** (1.58)
Ownership											-.38 (1.12)
Constant	-17.89 (6.96)	18.95*** (2.15)	-.05 (.07)	-.55*** (.84)	-2.57** (.97)	-2.11* (,85)	-3.57* (1.63)	-6.08*** (1.44)	-2.74** (1.01)	-1.93+ (1.16)	-4.14 (1.83)
Rho									.67*** (.36)	-.99*** (.27)	.98*** (.27)
Sigma									-.33*** (,02)	2.63*** (.06)	-1.04***
F	18.48***	4.04*	24.00***	26.95***							
R-squared	.52	.11	.56	.63							
Log-Likelihood					-65.75	-67.57	-57.13	-35.77			
Log pseudo-likelihood									-596.85	-587.03	-589.91
Chi-squared					45.09***	41.45***	62.33***	105.06***	71.67***	68.59***	55,23***
Pseudo-R^2					.26	.24	.35	.59			

[a] *Coefficients are unstandardized. Standard errors are in parentheses.*
[b] *Dependent variable (joint patent: Yes = 1, No = 0).*
† p < .10.
**p < .05.*
***p < 0.01.*
****p < 0.001.*
N = 116.

DISCUSSION AND CONCLUSION

In this study, we sought to understand the factors that influence joint patenting activity in biotechnology alliances. This topic has received little attention in the literature. As a small step in this direction, we suggest that the ex-ante allocation of control rights and resource attributes may explain the ex-post division of property rights, and specifically, joint IP ownership in R&D alliances. Joint patenting activity is directly related to the ex-ante allocation of control rights. An R&D alliance probably leads to joint patenting when the biotechnology firm retains ex-ante control rights. Our results also show that joint patenting activity is related to the firms' resource attributes such as the degree of technological specialization and technological complexity. On the one hand, technological specialization has a negative effect on joint patenting activity; on the other hand, complexity increases the probability that the firms will file a joint patent. These two contradictory effects stem from the fact that complexity is highly likely to increase with an increasing number of technological fields in which the R&D activities are conducted (the correlation between these two attributes is negative and significant in our sample). The negative effect of the degree of firm specialization on joint patenting is strengthened when the partners have high complementarity. In other words, with less technological overlap, partners have less interest in filing a joint patent, more particularly when they are strongly specialized. Nevertheless, our assumed negative relationship between firms' technological specialization and joint patenting is mediated by the ex-ante control rights that the biotechnological firm retains. These results suggest that joint patenting can be considered a strategic choice—indeed, a firm's anticipated boundary. This does not rule out the hypothesis that joint patenting activity may be, in some cases, an obligation. When knowledge is too complex, it may be difficult to divide IP at the conclusion of the joint R&D process without losing the benefits of this resource attribute. In fact, when the technology is too complex, the firms must either introduce more stringent provisions in the R&D contract to the extent that their bargaining power allows in the negotiation stage, or the firms must share IP rights at the end of the alliance process. In the case of a specialized firm, the ownership of specialized technological assets combined with a strong financial position can increase the firm's bargaining power at the beginning of the alliance formation. This bargaining power facilitates the introduction of specific control rights in the alliance contract. On the other hand, the firm may be more reluctant to share IP property rights with its partner under a joint patent because the intellectual property resulting from the collaborative process was developed based on the specialized firm's core competencies. Leiponen (2008) shows that firms that retain control rights to intellectual property are more likely to innovate than firms that yield control rights to their partners. In the case of individual patents, the party that owns the IP may not provide access to it in the future. In contrast, joint patenting provides guaranteed access to IP, and the possibility for the partner to license third parties without the co-owner's consent (in the USA), unless the contract specifies otherwise. In the absence of specific contractual constraints, the specialized firm may lose some of its core competencies. Two alternatives are then possible. 1) The firm cooperates due to strategic developmental needs, for instance, to cope with environmental conditions or a vulnerable strategic

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position (Eisenhardt & Schoonoven, 1996). In this case, cooperation may favor a successful alliance, and a joint patent may become an unanticipated obligation. 2) As the alliance relationship evolves, the firm may believe that the joint IP ownership that may result from the joint R&D process would be too risky. The firm would consequently reduce its commitment, leading to a failed alliance. Pisano (1997) refers to this as the "lemons" hypothesis in the market for know-how.

Although a joint patent is not the only criterion of alliance performance, it nevertheless conveys the success of the collaborative effort, even if disagreements over R&D output lead to a lawsuit between the partners. All this raises the question of the importance of ex-ante allocation of control rights to explain alliance performance. As Reuer and Ariño (2007) note, empirical studies on alliance performance factors might be subject to misattributions if they do not account for the various contractual provisions that firms can include in collaborative agreements. Our study assumes this perspective, and we believe that it makes several contributions and opens up useful avenues for future research. First, by exploring the determinants of joint patenting, we show how sharing ex-post property rights is contingent on the initial conditions for the alliance formation, and more specifically the allocation of ex-ante control rights and the firms' resource attributes. We underscore the importance of the allocation of control rights to the biotechnology firm. Essentially, we conclude that joint patenting activity is a complex phenomenon: resource attributes, and specifically technological specialization, initially influence the contract provisions and may have an impact on joint patenting in terms of the allocation of ex-ante control rights. Complexity may influence both the ex-ante and ex-post allocation of control rights. The central conclusion is that property rights theory and the resource-based view may complementarily explain joint patenting activity.

Second, our focus on initial conditions points to a fruitful albeit indirect approach to the question of value appropriation in R&D alliances, and consequently the performance of individual firms. As Adegbesan and Higgins (2010) contend, because alliance effects are difficult to isolate from other potential drivers of firm performance, the analysis of value appropriation can provide an alternative route. Third, we argue that a firm's degree of specialization drives its preferences for control rights. As Haeussler and Higgins (2012) note, the allocation of control rights follows the benefits of specialization in knowledge. This suggests that a firm's specialization increases its bargaining power during the negotiation stage, therefore assuring ex-post property rights. This view is in line with property rights theory, whereby property rights should be allocated to the party who can have the strongest marginal impact on the outcome. Fourth, from a managerial perspective, our research focuses on the importance of the alliance negotiation phase, when the partners decide how they will share ownership and appropriate the value of the outcome. This paper should sensitize managers to the fact that IP is both the input and output of R&D alliances. IP protection is not limited to the protection of invested assets: it may also include output protection and ownership. The choice to file a joint patent therefore depends on the characteristics of the firm and its involvement in the alliance.

Limitations and future research

Several avenues for further exploration can be suggested. First, alliance relationships tend to evolve and develop. One key alliance performance factor is the flexibility of the partners and of the alliance itself. Contracts are therefore frequently renegotiated (Reuer & Ariño, 2002). The motivations for these changes may affect joint patenting activity, and future research could take these changes into account. Second, our study was limited to a specific US legal environment. Future studies could explore joint patenting activity in different countries in order to develop a more generalizable model. Moreover, given the growth rate of international R&D alliances, studies could focus on the motivation for joint patenting in a global economy. Third, as we have assumed 1) efficiency arguments with regard to joint patenting activity and 2) the potential negative consequences of joint patenting activity, we do not analyze the implications of joint patenting activity on a firm's performance or its innovation rate, for example. It would be useful to empirically determine the various benefits and risks that firms can potentially derive from joint patenting activity. A more complete model would incorporate both the causes and consequences of joint patenting activity. In conclusion, our study opens the way to further empirical investigations of the critical issue of how outcomes and foreground knowledge are shared and divided in R&D alliances.

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