Contractibility and the Design of Research Agreements*

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Abstract

We analyze how variations in contractibility affect the design of contracts in the context of biotechnology research agreements. A major concern of firms financing biotechnology research is that the R&D firms might use the funding to subsidize other projects or substitute one project for another. We develop a model based on the property-rights theory of the firm that allows for researchers in the R&D firms to pursue multiple projects. When research activities are non-verifiable, we show that it is optimal for the financing company to obtain the option right to terminate the research agreement while maintaining broad property rights to the terminated project. The option right induces the biotechnology firm researchers not to deviate from the proposed research activities. The contract prevents opportunistic exercise of the termination right by conditioning payments on the termination of the agreement. We test the model empirically using a new data set on 584 biotechnology research agreements. We find that the assignment of termination and broad intellectual property rights to the financing firm occurs in contractually difficult environments in which there is no specifiable lead product candidate. We also analyze how the contractual design varies with the R&D firm's financial constraints and research capacities and with the type of financing firm. The additional empirical results allow us to distinguish the property-rights explanation from alternative stories, based on uncertainty and asymmetric information about the project quality or research abilities.

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I. Introduction

Understanding the determinants and limits of contract design is central to numerous fields of economic analysis, including organizational economics, labor economics, and corporate finance. An important distinction, introduced by the literature on incomplete contracts, is the observability and verifiability of actions and outputs on which the parties would like to contract (cf. Hart (1995)). If key variables are not verifiable in front of judges, the contracting parties have to find alternative mechanisms to induce the expected behavior, such as (re-) allocating asset ownership.

This paper analyzes how the design of contracts varies as underlying variables become harder or easier to pin down. We compare, both theoretically and empirically, how the decision rights of one party depend on the contractibility of the effort to be performed by the other party. The empirical context is the U.S. biotechnology industry. Innovative activities in the biotechnology sector frequently take the form of research agreements between biotechnology companies ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The research tasks to be performed by the biotechnology company can sometimes be specified in the contract, especially if the parties have a predetermined lead product candidate and the biotechnology researchers simply have to perform a series of specifiable experiments. Oftentimes, however, no such lead product candidate exists and it is hard to write a contract on what the researchers should be working on. In this paper, we analyze how the contract design covaries with such contracting difficulties.

The analysis of "real-world contract design" in light of the theoretical work on contracts has advanced rapidly in the field of complete contracts. A considerable number of papers identify and test the implications of asymmetric information and moral hazard.[1] Empirical research relating to incomplete contracts has been much sparser. This may reflect empirical difficulties in pinning down theoretical concepts such as observability, verifiability and even incompleteness. Two leading exceptions are the work by Kaplan and Stromberg (2003 and 2004), which provides evidence on the empirical incompleteness of contracts, and the work by Baker and Hubbard (2003 and 2004), which confirms the role of asset ownership to deal with limits to contracting. The former research gets around the empirical problem of translating abstract theory into tangible empirics by providing an exhaustive description of all contractual elements. The latter research benefits from a switch in the monitoring technology of truck drivers, which allows for contracts previously not feasible. The approach taken in this paper resembles most closely the latter. We identify an empirical proxy for contractibility and relate it to variations in contract design. A large, hand-collected data set on research agreements allows us to address empirically a number

[1] See the survey by Chiappori and Salanie (2003).

of concerns plaguing that literature, such as unobserved firm characteristics (via firm fixed-effects and firm-level controls), and to test directly competing explanations.

Contracting difficulties are a key concern in biotechnology research agreements since the financing company and research firm pursue different goals. While it is the objective of the financing company to develop a certain viable and profitable drug, the researchers of the R&D firm are also interested in advancing research projects underway in other research agreements or stand-alone projects. Moreover, the researchers are typically more academically oriented and may focus on different types of research even within the collaboration project. The risk for the financing company is that the biotechnology researchers take the money provided for the collaboration but devote their energies to other projects. This is in fact a major concern of pharmaceutical companies entering research agreements and has been termed "project substitution" or "project cross-subsidization."

We explore how the collaborating firms address this incentive conflict contractually. Empirically, we find that when a research partnership is initiated without any specifiable lead product candidate and it is thus not possible to contract on the exact nature of the research activities, the contracting parties endogenously generate decision rights to govern the relationship. These decision rights typically give the financing company the unilateral and unconditional right to terminate the research agreement while obtaining broadened access to the intellectual property rights. In fact, pharmaceutical firms often assert that the only remedy to the lack of contractibility is to have the right to terminate the research collaboration. No matter how carefully designed the contract, they argue, constructing a transaction that forestalls all contingencies is impossible. As a result, firms pay an enormous amount of attention to negotiating termination rights. These terms have been described as "probably the most heavily negotiated (at least in terms of time) provision" in biotechnology research agreements (Somers (2003)). Moreover, these contracts often specify that, in case of termination, the financing firm will maintain extensive access to the intellectual property of the prior research. The rights accruing to the financing firm in case of termination are broader than in case of continuation and go beyond the specific application targeted by the original research collaboration.

We provide a theoretical explanation of the observed contract design, based on the property-rights theory of the firm, in particular Hart and Moore (1988) and Nöldeke and Schmidt (1995). Our model allows for multi-tasking of researchers in the R&D firm in the sense of Holmström and Milgrom (1991). We derive the option to terminate while obtaining broad rights to the terminated project as an endogenously generated decision right that allows the financing company to act upon an observable but not verifiable variable, namely the success of the (joint) research and expected marketability of the product. The optimal contract specifies different payments in case of termination and in case of continuation to ensure that the financing company

terminates if and only if the R&D firm diverts effort from the collaboration into other projects. It also specifies that, in case of termination, the financing firm will obtain the broadest access to the intellectual property of the research collaboration.

This allocation of property rights is profit maximizing for the financing company if the R&D company is financially constrained. Assigning broad property rights to the financing company – beyond the originally targeted research object – is likely to induce some loss of surplus. After all, it is exactly this type of broader research the financing company would like to prevent the R&D company from undertaking. The rationale, then, for such an inefficient assignment of intellectual property rights lies in the need to generate the right incentives for the research company. Since the R&D firm has no or little liquidity, it cannot compensate the financing company for continuation payments ex ante or commit to "negative payments" in case of termination. Reducing the R&D company's property rights in case of termination minimizes the financing company's required payment in case of continuation for a given (optimal) payoff difference between continuation and termination for the R&D company.

The financial constraints of the R&D company make option contracts costly for the financing company. The pharmaceutical company will typically extract less profit than in a complete-contracts world, in which it can contract directly on the type of research activity. Therefore, whenever it is possible to contract on details of the research to be undertaken by the R&D company, the financing company will rather employ such a complete contract in lieu of termination rights. When contracting on research is not possible, the financing company may instead employ the option contract.

By the same logic, our model also implies that an option contract is particularly likely if the outside options of the financing company are high. For example, the financing company can credibly threaten to terminate the agreement if it profits sufficiently from the broader rights it obtains in case of termination, even without the continued collaboration of the R&D company. To prevent the financing company from exercising the termination option and using the intellectual property in collaboration with other firms and researchers, the R&D firm will be willing to focus on the collaboration project even if continuation payments are not too high. The model thus predicts that, the greater are the financing firm's outside options, (a) the stronger should be the correlation between option-contract design and non-contractibility and (b) under non-contractibility, the more common should be the option contract.

Similarly, if the biotechnology firm is less financially constrained, the option contract may be less costly, since the R&D company could commit to payments in case of termination. On the other hand, a liquid R&D company could also assume the role of the residual claimant, rendering the option contract unnecessary. Thus, while our model does not have specific predictions about contract design in research agreements with liquid biotechnology firms, the

option-contracts design should be most strongly correlated with the lack of contractibility in research agreements with financially constrained R&D firms.

The predictions of this incomplete-contracts interpretation of the observed contract design are borne out in the empirical analysis. Research agreements employ the termination clause (with expanded access to the intellectual property) when the exact nature of the research cannot be contracted upon since the lead product candidate cannot be specified. Moreover, the correlation effect is strongest if the financing company is not a pharmaceutical company but a biotechnology company. These additional findings are consistent with our model's prediction that the correlation of option design and non-contractibility is stronger if the financing company's alternative use of the intellectual property outside the original research collaboration is more valuable: the large (financing) biotechnology company is more likely to be able to use the intellectual property rights in a profitable way than a pharmaceutical company would be. Thus, the threat of termination is larger and the option contract becomes cheaper. Similarly, we also find that the correlation effect is strongest among the most financially constrained firms. As predicted by the model, the illiquidity of the R&D company makes option contracts costly and reduces the use of those contracts to the cases of non-contractibility. To sum up, cross-subsidization appears to be addressed by option contracts whenever direct contracting is particularly hard and the option contract is not too costly.

We employ additional empirical tests to distinguish the incomplete-contracts hypothesis from other explanations of the correlation between the lack of a contractually specified lead product candidate and the termination and intellectual property reversion clauses. A number of the alternative explanations, such as heterogeneity in the extent of uncertainty, the degree of informational asymmetry, or the "abilities" of the R&D company, would predict a correlation with (specific) termination clauses, but not necessarily with the reversion of intellectual property rights. Such a correlation, however, cannot be found in the data. In addition, proxies for the "research quality" of the R&D firm help to rule out the hypothesis that termination clauses are a sorting device.

Overall, this paper serves three purposes. First, we shed light on a key incentive conflict in research collaborations, project cross-subsidization. We characterize the nature of this incentive conflict as moral hazard in a multi-tasking framework. Second, we provide new details of the empirical contract design of research agreements. In particular, we point to the frequent use of unilateral and unconditional termination rights combined with broadened access to the intellectual property of the research project. Third, we explain how the combination of termination and broadened access to property rights may remedy incentive problems and contracting difficulties more generally. Our explanation is based on the assumption of contractual incompleteness, which appears to be plausible in research agreements and many other settings.

While our empirical application is research agreements in the biotechnology sector, we believe that termination rights (and payments) combined with ownership allocation may be used in other settings to overcome the limits to contractual complexity. Venture capitalists typically provide capital in stages and have the right not to refinance a firm, which Gompers (1995) and others have attributed to the difficulty of writing a contract that foresees all contingencies. Not providing any refinancing is often equivalent to driving the company into bankruptcy, in which case the venture capitalist (who as a preferred stock holder is a senior claimant) ends up owning all the assets. A second example is the rising age-earnings profile in companies. Given that employment contracts cannot specify all work-related contingencies ex ante, the increase helps insure that employees perform as their firm would like them to. In fact, firms face a similar problem of financial constraints on the part of the employees as pharmaceutical companies do with biotechnology firms. To both set incentives right and to allow the employer to extract the surplus from the employment relationship, employees would need to post a bond ex ante. Lazear (1979) interprets mandatory retirement as a substitute for such a bond given that employees are often unable to post it ex ante.

Empirical tests of the property rights theory of the firm have largely focused on "make or buy" decisions (e.g. Monteverde and Teece (1982); Baker and Hubbard (2003); Acemoglu, Aghion, Griffith, and Zilbotti (2003)). The theoretical literature, however, pioneered by Grossman and Hart (1986) and Hart and Moore (1988, 1990), goes beyond the question of integration and outsourcing. In theory, the contracting parties may remedy contractual incompleteness by assigning any suitable decision right that governs the actions of the other party even though the actions themselves are not contractible. Theory thus implies a much broader arena for empirical tests than "make or buy" decisions. Since integration decisions are affected by numerous considerations, such as diversification, market power, or deregulation, broader tests are an important addition to our understanding of real-world contract design and the empirical relevance of the property-rights approach.

Our paper differs from much of the previous work on strategic alliance and venture capital contracts in de-emphasizing the optimal allocation of firm ownership. Most of the literature, such as Cornelli and Yosha (2003), Dessein (2003), Schmidt (2003), and Nöldeke and Schmidt (1998), focuses on the transfer of control rights over a company or joint venture between the contracting parties. In research agreements, however, the financing company may not have much interest in owning the entire R&D firm but rather in developing one specific product. Moreover, in contrast with the classic relationship-specific investment problem, the researchers of the financing company may not be able to benefit from residual control rights, simply because they do not have the relevant research expertise. Our framework relates to the literature on financial contracting and, in particular, Aghion and Bolton (1992). As in Aghion and Bolton, we

consider the decision of a financing company to provide capital to another company in return for some decision rights. However, while the rights are contingent on default in Aghion and Bolton, we consider non-contingent rights, namely, the unconditional option to terminate. And, while Aghion and Bolton assume fixed transfers, payoffs are contingent (on the decision to exercise the option) in our framework.[2]

On the empirical side, our paper relates to previous papers studying the design of real-world contract design in strategic alliances (Robinson and Stuart (2004)) or venture capital contracts (Kaplan and Stromberg (2003)). Rather than focusing on the full set of contractual contingencies as in those papers, we illustrate the role of contractibility of outcomes and other variables for real-world contract design by studying its covariance with specific contractual clauses (namely option rights to terminate).

Finally, the specific incentive conflict of "academic" versus "commercial" research has been analyzed outside of contract theory. The explosion of knowledge in biology and biochemistry in the 1970s triggered the adoption of scientific approaches, or "open science" in Dasgupta and David's (1994) terminology, within for-profit organizations such as major pharmaceutical companies (Henderson and Cockburn (1994); Gambardella (1995)). A number of firms encouraged researchers to pursue basic research, in addition to the applied projects that characterized these organizations. The firms that did so enjoyed substantially higher R&D productivity than their peers, apparently because their research were better able to identify promising scientific developments and because the interaction with cutting-edge research made these firms more attractive to top scientists.[3] At the same time, the encouragement of "open science" processes has led to difficulties in measuring performance and designing incentive schemes (Cockburn, Henderson, and Stern (1999)). In fact, partly due to these challenges, firms appear to be moving to less of an emphasis on basic science in their research facilities (for a discussion, see Rosenbloom and Spencer (1996)).

The remainder of the paper is organized as follows. In Section II, we present stylized facts on research collaborations in the biotechnology sector, the incentive conflicts between the contracting partners, and the empirical contract design. Section III presents a model that

[2]Our approach is close to Aghion and Tirole (1994) in emphasizing the inefficiency implications of financial constraints. Similar to their work, our model suggests that financial constraints of the research unit may prevent the first-best outcome if research efforts are non-contractible, and that the allocation of product ownership helps to alleviate this problem. Our model corresponds to a situation in Aghion and Tirole where the research unit has higher marginal impact on the output, but the "customer" (i.e., the financing company) has all the bargaining power. Differently from the Grossman and Hart (1986) setting employed by Aghion and Tirole, though, we do not explore the impact of incentives and financial constraints on ex-ante product ownership, but rather on the "right to govern the relationship," in particular, termination and claims to the intellectual property. Similar to Baker, Gibbons, and Murphy (2002) and Hart and Holmström (2002), we emphasize a contracting problem that differs from the classic problem of relationship-specific investment.

[3]Similarly, collaborations between university research labs and for-profit organizations are organized more often as sponsored research (instead of ex-post licensing) if more basic research is involved (Thursby and Thursby (2003)).

reconciles the empirical contract design with the observed conflict of interest. We test the predictions of the model empirically on a novel contracts data set, introduced in Section IV. The empirical tests of our model's predictions and alternative hypotheses are in Section V. Section VI concludes the paper.

II. Conflicts of Interest in Biotechnology Research Collaborations

Innovative activities in the biotechnology sector have been increasingly financed via research collaborations. While the initial biotechnology companies relied primarily on capital raised from the public market, research alliances surpassed public offerings in the 1990s as the dominant source of financing for these firms.[4] These research collaborations consist of three phases, a research, a development, and a marketing and sales phase. Typically, the pharmaceutical company provides the initial financing and the biotechnology company provides the bulk of the research, though employees of the larger firm may undertake some as well. The "development" of the drug is undertaken jointly. Finally, marketing and sales are mostly in the hands of the pharmaceutical company. The research and development phases are characterized by considerable uncertainty as to project success. In 200 alliances entered into between 1980 and 1995 analyzed by Lerner, Shane and Tsai (2003), only 14% had led to an approved project by December 1998. Of those in the discovery stage at the time of the alliance signing, only 5% had led to an approved drug: in fact, only 31% had reached clinical trials at all by this point.

As the dominant research-performing entity, the biotechnology firm typically receives the intellectual property rights, but commits to license the relevant patent holdings and know-how to its partner for the life of the agreement (and in many cases thereafter). The contract frequently delineates the right to manufacture the product, which may be assigned to one of the parties or divided between the two. Most of the profits from the final project go to the pharmaceutical company, though the biotechnology company also reaps a certain percentage via the royalties from licensing.

The pervasiveness of research agreements between pharmaceutical and biotechnology companies is puzzling since the interests of the two partners are typically not fully aligned and since it is often hard to contract on research activities. We conducted a number of interviews with executives specializing in management, technology transfer, and legal affairs to clarify these issues. From these interviews, we learned that project substitution and project cross-subsidization by the biotechnology researchers are major concerns of pharmaceutical companies entering research agreements. While it is the objective of the financing company to develop a certain

[4] See Lerner and Merges (1998).

viable and profitable drug, the R&D firm has multiple interests. On the one hand, the researchers in the biotechnology laboratories of the R&D firm are also interested in developing the proposed drug and ensuring future cash flows. On the other hand, they are typically juggling several research projects. Some of these projects may be commercialized in collaboration with other pharmaceutical or biotechnology firms, on terms that may be more favorable than this collaboration. In addition, the R&D firm may be seeking to develop wholly owned products, from which they will receive all the profits. Success in these solely developed products may also be particularly valued by the equity markets as an indicator of the acumen of the R&D firm's management. As a result, the researchers in the R&D firm may be tempted to employ resources from a specific research agreement for other projects.[5]

In addition to these commercial conflicts, an additional challenge relates to the complex goals of the biotechnology researchers. Researchers in biotechnology companies are typically much more academically oriented than those in pharmaceutical companies. Biotechnology firms are often founded and guided by long-time academics who may still want to impact the academic discussion; they often employ post-doctoral students who are considering an academic career in the future; and their reputation in the market for future research agreements depends to a large extent on the external assessment of their research abilities. To cite a characteristic example, the researchers of the biotechnology company may want to spend time and effort running additional experiments to satisfy academic requirements for a publication in a top journal, even though there is already enough evidence to start the process for approval by the U.S. Food and Drug Administration for the drug and the financing partner would like to press ahead with the approval process. All these pressures may lead to biotechnology firms pursuing projects or research activities that are more fundamental than the pharmaceutical company would prefer, and often seeking to publish these results before the pharmaceutical company prefers. These forms of conflict seem very important in this context, and have not been previously explored in the literature on research collaborations.[6]

A variant of this incentive problem is that researchers of the biotechnology firm tend to terminate unsuccessful projects too late. This can happen for several reasons. First, as described above, additional research on a given project can be beneficial to the researcher's scientific reputation even though it is not profit maximizing for the pharmaceutical company. Second, researchers and especially founders of biotechnology firms may be "attached" to the initial

[5] For instance, in 1993, established biotechnology firm Alkermes sued the smaller firm, Cortex Pharmaceuticals, which it had entered into a research agreement with the year before. It alleged that Cortex's research on a calpain-inhibiting drug for cerebral vasospasm violated Alkermes' exclusive right to develop applications for neurological disorders (*Alkermes, Inc. v. Cortex Pharmaceuticals Inc.*, Civil Docket no. 93-CV-12532, U.S. District Court for Massachusetts (Boston), 1993.).

[6] Stern (2003) points out that scientists are willing to accept lower wages in return for being able to pursue more science-oriented research.

biotechnological component employed in a research agreement since it constitutes their principal discovery. Such behavior has been labeled "founder syndrome." In fact, we learnt in the course of our interviews that founders often leave the company when the initial technology researched is finally abandoned, asserting that they do not "morally own" the company any more. Third, it appears to be hard for researchers to admit that a project ought to be terminated and they thus tend to hold on to projects for too long.[7] Fourth, the researchers in the biotechnology companies may have empire-building preferences and thus attempt to maximize the number of ongoing projects.

These types of moral hazard problems are closely related to the project cross-subsidization problem laid out initially. Here, the biotechnology researchers do not work on a different project than the pharmaceutical company would like them to work on, but they continue working on a project even though the pharmaceutical company would like them to declare the research to be either completed or to have been unsuccessful. Similar to the original cross-subsidization problem, it is often hard for pharmaceutical companies to determine when the biotechnology researchers are engaging in such undesired research. Both from a modeling and an empirical perspective, we can re-interpret project substitution as substitution of project termination with undesired research and thus capture these latter variants.

An illustration of the possibilities of opportunistic behavior that can emerge from the behavior of the R&D firm is the research agreement between ALZA, a California-based drug delivery company founded in 1968, and the Swiss pharmaceutical giant Ciba-Geigy.[8] The two firms signed a research agreement in 1978. ALZA also engaged in a variety of independent activities, including forming alliances to exploit technologies that did not conflict with the topics being jointly explored with Ciba-Geigy.

Due to ALZA's financial weakness, Ciba-Geigy was able to obtain vast control rights, such as eight of ALZA's eleven board seats, majority voting control, extensive information rights, and the ability to guide 90% of ALZA's research activities through a number of review panels that were dominated by Ciba-Geigy representatives. Nevertheless, numerous tensions arose over the exact type of research the ALZA researchers should be conducting. In particular, Ciba-Geigy was concerned about other research projects and research collaborations of ALZA. ALZA representatives kept seeking to establish collaborations with third parties. Ciba-Geigy found it difficult to control the activities of ALZA despite these seemingly ironclad control rights. While the boards ultimately approved most of ALZA's requests, ALZA representatives became frustrated at the long delays associated with the process. As a result, ALZA scientists began

[7]Cf. Stulz (1990).

[8]This account is based on Angelmar and Doz (1987-1989).

bypassing the various review panels and directly contacting senior Ciba-Geigy officials for permission to engage in outside arrangements. While detailed reporting and monitoring processes had been stipulated in the original agreement, these proved very difficult to enforce. Ciba-Geigy officials believed that ALZA scientists were publishing materials in journals that would have been best reserved for the collaboration. Ciba-Geigy officials, worried that their proprietary technology might be disclosed in these publications or employed in ALZA's collaborations with other pharmaceutical firms, became increasingly reluctant to disclose their own technologies in the area of drug delivery to ALZA. Ultimately, these tensions led to the dissolution of the research collaboration at the end of 1981. These conflicts, while perhaps extreme, illustrate the difficulties that the types of problems delineated above can have on parties.

Only in a subset of these cases can the parties remedy this incentive conflict directly by specifying the exact nature of the research activities to be undertaken by the researchers or by conditioning on the outcomes of specific tests. In this subset of cases, the parties have typically identified a specific lead product candidate at the beginning of their collaboration. It is thus relatively easy for them to separate out unrelated research. In many cases, however, the exact lead product candidate to be tested is not yet specifiable and the research agreement is entered without a clear and concrete product in mind. The research agreements, then, have to account for contractual incompleteness – for having "too many" future contingencies that are "too hard to think of" to contract upon them. The risk for the financing company is then that the biotechnology company forms multiple research agreements around a single promising but poorly understood compound, partnering with one firm to address one disease and with another to address a second.[9] In these cases, it is likely to be very difficult to delineate the boundaries of each project. In this paper, we are exploiting exactly this variation in contractibility, both from a theoretical and an empirical perspective.

III. Model

We present a simple model that illustrates how variations in contractibility affect the design of the research agreements. We consider a financially constrained research company *R* and a financing company *F*, both risk-neutral. (All variable definitions are summarized in Appendix A.) The model distinguishes between an initial research phase and a reduced-form development, marketing, and sales phase, as depicted in Figure 1. If the financing company provides initial financing *I*–e. g., to set up a laboratory–then *R* can perform research. *R*'s research yields an

[9] Given these conflicts, it is not surprising that a significant fraction of research collaborations are terminated before their contractually specified life (Lerner, Shane, and Tsai (2003)). Indeed, in a number of cases, the failure of the biotechnology company to assign activities allegedly in a research agreement's scope to their collaborative partner has triggered litigation. See footnote 5.

intermediate product, the production technology. If advanced through development, marketing, and sales, the production technology generates two types of surplus. The "narrow" (or "commercial") surplus, denoted by N, results from the sales of the envisioned marketable product of the research collaboration. The "broad" (or "scientific") surplus, denoted as B, captures both profits and scientific reputation from unrelated discoveries, which are less valuable to F. Both types of surplus are ex ante uncertain.

In the initial research phase, the biotechnology researchers can either focus on the narrowly defined research project or engage in broader research activities. Narrow (commercial) research effort e_N leads to a technology that generates a higher expected level of commercial surplus, $\overline{N}$, than broad (commercial) research e_B, which results in $\underline{N}$. At the same time, the technology resulting from e_N generates only a low expected level of scientific surplus, $\underline{B}$, while e_B would result in a high level, $\overline{B}$. Our analysis focuses on the case $\overline{N} > I$. Both the high and the low level of both types of surplus remain uncertain at the end of the research phase.

How much narrow and broad surplus the parties can extract also depends (i) on their collaboration after the initial research phase and (ii) on the allocation of property rights.

As for the first determinant, we assume that the parties can extract the full amount of narrow surplus N if they continue to collaborate. They can extract only a portion α, $\alpha \in (0,1)$, if the collaboration is terminated after the research phase. The ex-post efficiency losses from breaking up the research relationship and continuing the narrow research with another partner reflect both the specialization of biotechnology researchers and the search costs associated with finding a new partner. Specifically, the development phase involves the preliminary production and also the approval process at the FDA. Changes and adjustments to regulatory requirements will induce the parties to "go back to science" and thus benefit from the efforts of R as well as from the procedural and production know-how of F. The amount of broad surplus B, on the other hand, does not depend on the continued collaboration of the two initial research partners. It captures the value of future projects with different research partners and general scientific reputation. (We will not consider explicitly any development and transformation from research technology into realized surplus.)

As for the second determinant of whether the parties garner the full surplus, the relevant property rights in our context are licensing and intellectual property rights. The surplus is non-contractible and accrues to the holder of the intellectual property rights. By default, this is R as the patent holder unless F has obtained the rights from R. Rights to the narrow surplus and to the broad surplus can be contracted on separately.[10] Narrow rights (typically licensing rights) allow

[10] We assume that the relevant technologies entail an exclusive license. This assumption is consistent with the nature of typical agreements, where the financing firm is granted exclusivity in an important range of applications.

F to sell the envisioned product of the collaboration and to reap the surplus *N* from its sales. Broad rights allow *F* to develop and sell the less related side products.

Finally, we assume that *R* cannot extract any portion of *N* without granting *F* the narrow (licensing) rights. This assumption captures that the final marketing and sales stages rely on the capacity of *F* to undertake large-scale manufacturing as well as on *F*'s marketing and distribution channels. Given *R*'s financial constraints as well as the stochastic and non-contractible nature of *N*, *R* needs to grant *F* the narrow (licensing) rights to induce *F*'s collaboration, and thus *F* obtains the narrow surplus. Otherwise, the narrow surplus is lost.

This does not hold for *B*. We assume that *R* can extract the full amount of broad surplus *B* if *R* retains the broad rights, but that *F* can extract only a portion εB, $\varepsilon \in (0,1)$ if granted the broad rights. This assumption captures the different nature of *B* compared to *N*. Future research, building on the broad technology, may lead to enhanced scientific reputation, which is more valuable to the academically oriented researchers in the biotechnology company than to the pharmaceutical company. Moreover, to the extent that *B* reflects the sales potential of unrelated products, it may prove useful to *R* for other (current or future) research collaborations with companies that have a different specialization and value the specific outcome more highly, but it is of little interest to *F*. We also assume that

$$R \text{ chooses } e_B \text{ if indifferent between } e_N \text{ and } e_B. \qquad \textbf{(A.1)}$$

Assumption A.1 can be interpreted as a reduced-form substitute for modeling explicitly non-transferable benefits of choosing e_B. It may capture unalienable benefits to the biotechnology researchers from pursuing the broader, more scientific research, such as acquiring non-transferable general human capital.

We assume that the financing company *F* makes a take-it-or-leave-it offer to *R* and extracts the entire surplus beyond *R*'s reservation utility. This assumption reflects that there are many biotechnology companies seeking funding, relative to the number of potential capital providers. We do not model the effort costs of *R* explicitly. Rather, we assume that *R* is willing to sign a contract only if the expected payoff amounts to at least the expected value of the broad rights after narrow research, $\underline{B}$:

$$\text{The reservation utility of } R \text{ is } \underline{B}. \qquad \textbf{(A.2)}$$

For simplicity, we focus on the case[11]

$$\underline{B} > \varepsilon \overline{B}. \qquad \textbf{(A.3)}$$

In order to illustrate the role of option rights, we first derive the optimal contract under the assumption that the research effort of *R* is contractible. Next, we derive the optimal no-option

[11] This assumption simply reduces the number of cases to be considered (see Appendix B).

contract under the assumption that R's research is observable[12] but not verifiable. We then introduce option rights and analyze whether they allow the financing company to extract a greater share of the surplus. In particular, we consider the option to terminate the research collaboration after F has observed R's effort and the research output of the initial research phase. Note that this implies that collaboration in the development phase is contractible and that the courts can observe termination, i.e., which of the parties (if any) decided not to continue the collaboration after the research phase. We assume

F terminates if indifferent between termination and continuation. **(A.4)**

The focus on option rights to terminate the collaboration reflects the empirical purpose of the model. While we *do* derive the optimality of a specific option contract among all option contracts that condition intellectual property rights on the decision to terminate, we do not explore the optimality of other option contracts.[13]

As depicted in Figure 1, the time-line is as follows. At $t = 0$, the two parties enter into a contract. The contract specifies:

(i) the initial payment I by the financing company F at $t = 1$,

(ii) the conditions for termination (if any) at $t = 2$,

(iii) the payments from F to R at $t = 2$,

(iv) the rights F obtains from R, which may be narrow or broad.

After the initial investment I and research effort e, the parties observe the intermediate research output and conditional expected values of N and B. In the case of option contracts, the option holder decides whether to continue the research collaboration, and R obtains the resulting payment. The narrow surplus is realized after commercialization at $t = 3$. The payoff from broad surplus is generated via different (unmodeled) research activities in the future at or after $t = 3$. Thus, R cannot use these payoffs for payments to F. In fact, since R is credit constrained, there is no possibility of monetary transfers from R to F and hence, effectively, no bargaining between the two parties.[14]

[12] We also developed an alternative model specification where F cannot observe e directly but infers it from the intermediate research output at the end of period 1. The alternative model also removes the assumption that the final surplus N is non-contractible (which is a simplified way to capture the role of F in the last phase of the collaboration and the potential moral hazard problems) and allows for royalty fees. Introducing signal extraction and surplus sharing complicates the model, but the basic trade-off and determinants of the use of option rights are the same.

[13] Most of the alternative option contracts are hard to implement practically, which can be captured with weak additional assumptions. Consider, for example, a contract that gives F directly the option to seize intellectual property rights (rather than a termination option, on which the rights are then conditioned). In practice, however, F cannot simply "seize" the rights from R, and it is hard to imagine a contract that obliges R to grant both narrow and broad rights at the will of F while continuing to collaborate.

[14] We therefore do not explicitly model the initial "bargaining process" between F and R. There is scope for bargaining after R has exerted the initial research effort e, however, and we will consider the bargaining process during renegotiation (under the assumption of no commitment) explicitly.

In the benchmark case where the type of research to be undertaken by R is contractible, the parties can condition (ii)–(iv) on the type of research effort e. In the case of limited contractibility, e is observable but not verifiable and (ii)–(iv) cannot be conditioned on e.[15] In the case of the option contract, one party may obtain the right to terminate the collaboration at the end of period 1. Whether or not the option-holder exercises the option right is verifiable, and (ii)-(iv) can thus be conditioned on continuation or termination.

Formally, a contract A specifies an action $a \in \{C, T\}$, where C stands for continuation and T for termination, payments $p_C \geq 0$ and $p_T \geq 0$ from F to R in case of continuation and termination respectively, and property rights o_C and o_T accruing to F in case of continuation and termination respectively.[16] With some abuse of notation, we will denote the case that F receives no intellectual property rights after action a as $o_a = \varnothing$, the case that F receives broad rights as $o_a = B$, the case of narrow rights as $o_a = N$, and the case of both broad and narrow rights as $o_a = B + N$. In the case of full contractibility, a, p_C, p_T, o_C, and o_T can be conditioned on $e \in \{e_N, e_B\}$; in the case of limited contractibility, they cannot. An option contract gives one party $i \in \{R, F\}$ the right to choose a and specifies the conditional payments and ownership rights. Note that giving R the option right makes the game equivalent to having R choose simultaneously e and a. Figure 2 summarizes the payoffs of both parties under different continuation (or termination) and intellectual property (IP) rights scenarios.

Contractibility. In the case of contractible effort, it is easy to see that F maximizes its payoff by inducing R to exert e_N and claiming only the narrow rights. F can simply condition a higher payoff on the desired action. The payoff of F is thus $\overline{N} - I$, and R's payoff is $\underline{B}$.

Note that this is not necessarily the surplus-maximizing outcome since $\overline{B} + \underline{N}$ may be larger than $\underline{B} + \overline{N}$. In this case, the financial constraints of the biotechnology company prevent the parties from agreeing on the first-best and having the biotechnology company compensate its partner ex ante, akin to Aghion and Tirole (1994).

Limited contractibility without options. If the type of research undertaken by R is observable but not verifiable, the parties cannot condition payments and actions on e. R will always choose e_B. Given Assumption A.3, it is profit-maximizing for F to acquire only the narrow rights since this dispenses with the need to pay R's reservation wage. Thus, F's expected payoff is $\underline{N} - I$, and

[15] As mentioned above (footnote 12), the alternative assumption that not e but only intermediate output is observable does not affect the basic insights about the use of option rights.

[16] We leave out the initial financing I since it does not vary across contracts.

R gets $\overline{B}$ if a contract is signed. However, if $\underline{N} < I$, the parties will not sign a research agreement and forgo the narrow and broad surplus. We denote the set of contracts that maximize F's profit (including "no contract") under limited contractibility in the class of contracts without options as A^*_{NO} and the resulting expected payoff for F as Π^*_{NO}, with $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$.

Limited contractibility with options. In order to overcome the contracting problem, the parties may generate other decision rights for which the outcome (i.e., the action taken) is contractible. We consider the option right to terminate the relationship after the biotechnology researchers have exerted their research effort and before the final surplus N is generated. We denote such contracts as $A_O = (i, p_C, p_T, o_C, o_T)$. We focus on option contracts that strictly improve F's payoff over the highest payoff F can obtain from a contract without options. We first show that an option contract that

- grants F the right to terminate after R's initial research effort and
- allocates both the narrow and the broad rights to F if F terminates, but only narrow rights if F continues

may yield a higher expected payoff for F than the second-best no-option contract (Lemmas 1 to 3). We then show that no other option contract can increase F's expected payoff as much or more beyond the highest payoff without options (Lemma 4) and derive the equilibrium contract design and payoff (Proposition 1). All results are derived in a setting without renegotiation. In Appendix C, we allow for contract renegotiation. There, we analyze explicitly when the derived option contract is renegotiation-proof (Lemma 5) and account for renegotiation when deriving the contractual choice of F (Proposition 2).

Lemma 1. *An option contract (i, p_C, p_T, o_C, o_T) with $i = F$, $o_C = N$, and $o_T = N + B$ implements e_N iff*

$$(1-\alpha)\overline{N} - \varepsilon\underline{B} > p_C - p_T \geq (1-\alpha)\underline{N} - \varepsilon\overline{B}. \qquad (1)$$

Proof. We first show that prices (p_C, p_T) satisfying (1) are necessary and sufficient to induce F to terminate if and only if R chooses e_B. Under the contractual provisions described in Lemma 1, F terminates upon observing e_B if $\underline{N} - p_C \leq \alpha\underline{N} + \varepsilon\overline{B} - p_T$, and F continues upon observing e_N if $\overline{N} - p_C > \alpha\overline{N} + \varepsilon\underline{B} - p_T$. Solving these two inequalities for p_C - p_T yields (1).

It remains to be shown that R chooses e_N, given F's conditional termination decisions. R receives payoff p_T for effort e_B and $\underline{B} + p_C$ for effort e_N. Hence, R chooses e_N if and only if $p_C - p_T > -\underline{B}$. This is implied by (1) since $p_C - p_T \geq (1-\alpha)\underline{N} - \varepsilon\overline{B} > -\varepsilon\overline{B} > -\underline{B}$ with assumption A.3. **Q.E.D.**

To provide some intuition, note that the upper bound of the price differential between continuation and termination, i.e., the left-hand side of double-inequality (1), ensures that F chooses continuation after e_N. Similarly, the lower bound and right-hand side of (1) ensures that F chooses termination after e_B. An option contract satisfying (1) relies on two main features to implement e_N. First, termination reduces the amount of narrow surplus F can obtain since $\alpha < 1$. Thus, holding other payoffs constant, F prefers continuation over termination. Second, F attains some of the broad surplus if allocated the broad rights since $\varepsilon > 0$. Thus, the allocation of broad rights can be used to make the threat of termination less costly to F.

Within the class of incentive compatible option contracts, satisfying (1), we can characterize the set of contracts that generate the highest profits for F. Denote the left-hand side of (1), $(1-\alpha)\overline{N} - \varepsilon \underline{B}$, as Γ and the right-hand side of (1), $(1-\alpha)\underline{N} - \varepsilon \overline{B}$, as Δ. The following Lemma characterizes the solution to F's maximization problem.

Lemma 2. *In the set of option contracts* $(F, p_C, p_T, N, N + B)$ *that implement* e_N*, any contract with*

$$p_C \begin{cases} = \Delta \\ = 0 \\ = 0 \end{cases} \text{ and } p_T \begin{cases} = 0 & \text{if } \Gamma > \Delta \geq 0 \\ \in [0, -\Delta] & \text{if } \Gamma > 0 > \Delta \\ \in (-\Gamma, -\Delta] & \text{if } 0 \geq \Gamma > \Delta \end{cases} \tag{2}$$

maximizes F's payoff.

Proof. The maximization program of F within the set of option contracts satisfying (1) is

$$\begin{aligned} &\max_{p_C, p_T} \overline{N} - p_C - I \\ &s.t. \; \Gamma > p_C - p_T \geq \Delta \\ &\quad p_C + \underline{B} \geq \underline{B} \\ &\quad p_C \geq 0, \; p_T \geq 0 \end{aligned}$$

where the first constraint ensures incentive compatibility for R and F, the second is the participation constraint for R, and the constraints in the last line capture that R is financially constrained. We can simplify this program to

$$\begin{aligned} &\min_{p_C, p_T} p_C \\ &s.t. \; p_C < \Gamma + p_T \\ &\quad p_C \geq \Delta + p_T \\ &\quad p_C \geq 0, \; p_T \geq 0 \end{aligned}$$

We distinguish three sub cases. (a) If $\Gamma > \Delta \geq 0$, then $p_C \geq 0$ is redundant and setting $p_C = \Delta$ and $p_T = 0$ is optimal. (b) If $\Gamma > 0 > \Delta$, then the non-negativity constraint on p_C is binding.

Therefore, setting $p_C = 0$ and picking any $p_T \in [0, -\Delta]$ is optimal. (c) If $0 \geq \Gamma > \Delta$, then the non-negativity constraint on p_C is again binding but setting $p_C = 0$ requires $-\Gamma < p_T \leq -\Delta$. **Q.E.D.**

Figure 3 provides a graphical illustration. Intuitively, Γ and Δ capture the gain to *F* from continuation (relative to termination) if *R* chooses e_N or e_B respectively. To ensure that *F* does not choose continuation after *R* exerted the undesired broad effort e_B, an optimal contract requires *F* to pay the gain from continuation after e_B, Δ, upon continuation (if there is a gain, i.e., if Δ is positive). If *R* were not financially constrained, *F* could implement termination at zero cost, i.e. with $p_C = 0$, by setting $p_T < 0$. But since that is not possible, the outside option of termination is not attractive unless *F* sets a positive continuation price. Similarly, to ensure that *F* does not choose termination after *R* exerted the desired narrow effort e_N, an optimal contract requires *F* to pay more than the gain from termination, –Γ, upon termination (if there is a gain, i.e., if Γ is negative).

Thus *F*'s total expected payoff is $\overline{N} - \max\{0, \Delta\} - I$, which we denote as $\hat{\Pi}_O$, and *R*'s total expected payoff is $\underline{B} + \max\{0, \Delta\}$. Denote the set of option contracts $(F, p_C, p_T, N, N + B)$ satisfying (2) as $\hat{A}_O$. We can now characterize the conditions under which $\hat{\Pi}_O > \Pi^*_{NO}$, i.e., under which *F* prefers any contract in $\hat{A}_O$ to any contract in the set of profit-maximizing contracts in the class of no-option contracts, A^*_{NO}.

Lemma 3. *The expected payoff of F under contract in* $\hat{A}_O$, $\hat{\Pi}_O$, *is higher than the expected payoff under contracts in* A^*_{NO}, Π^*_{NO}, *iff* $\overline{N} - \max\{\underline{N}, I\} > \Delta$.

Proof. If $\underline{N} - I \geq 0$, then $\hat{\Pi}_O > \Pi^*_{NO} \Leftrightarrow \overline{N} - \underline{N} > \max\{\Delta, 0\} \Leftrightarrow \overline{N} - \underline{N} > \Delta$, where the last biconditional follows from $\overline{N} > \underline{N}$. If $\underline{N} - I < 0$, then $\hat{\Pi}_O > \Pi^*_{NO} \Leftrightarrow \hat{\Pi}_O > \max\{0, \Delta\} \Leftrightarrow \overline{N} - I > \Delta$, where the last biconditional follows from the assumption $\overline{N} > I$. The two cases can be summarized as $\hat{\Pi}_O > \Pi^*_{NO} \Leftrightarrow \overline{N} - \max\{\underline{N}, I\} > \Delta$. **Q.E.D.**

Lemma 3 implies that an option contract is more likely to improve over the best no-option contract the higher the outside options of *F* in case of termination are, as captured by a high α and a high ε. For high enough α and ε, the gain from continuing after e_B is either negative ($\Delta < 0$) or at least smaller than the increase in narrow surplus if *R* exerts e_N rather than e_B

($\Delta < \overline{N} - \underline{N}$ or $\Delta < \overline{N} - I$). Intuitively, the more surplus F can reap without the continued collaboration of R – either narrow surplus (high α) or broad surplus (high ε) – the higher is the threat for R that F may terminate and the cheaper is the option contract for F.

So far, we have focused on one type of option contract, contracts in $\hat{A}_O$, and shown they induce R to exert narrow effort (Lemma 1) and may improve F's payoff (Lemma 3). We now consider the entire class of option contracts (i, p_C, p_T, o_C, o_T) and show that no other option contract can increase F's payoff over the highest non-option payoff Π^*_{NO} by as much or more than contracts in $\hat{A}_O$.

Lemma 4. *For all option contracts that are not in $\hat{A}_O$, the expected payoff Π_O is characterized by*

$$\Pi_O \leq \Pi^*_{NO} \quad \vee \quad \Pi_O < \hat{\Pi}_O .$$

Proof. See Appendix B.

Lemma 4 states that all other option contracts lead to lower payoffs than $\hat{A}_O$ whenever $\hat{A}_O$ is preferred to the unconditional contract. As long as F sticks to the unconditional contract whenever indifferent – e.g., due to other frictions in option contracting that are not modeled – we should thus observe either the unconditional contract or $\hat{A}_O$, but no other option contracts. We summarize the equilibrium contract design and payoff for F in the following Proposition.

Proposition 1. *If $\Delta < \overline{N} - \max\{\underline{N}, I\}$, F implements any option contract from $\hat{A}_O$ and obtains payoff $\hat{\Pi}_O = \overline{N} - I$. If $\Delta \geq \overline{N} - \max\{\underline{N}, I\}$, F implements any unconditional contract in A^*_{NO} and obtains payoff $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$.*

The optimality condition for the option contract, $\Delta < \overline{N} - \max\{\underline{N}, I\}$, i.e., $(1-\alpha)\underline{N} - \varepsilon\overline{B} < \overline{N} - \max\{\underline{N}, I\}$, is likely to be satisfied if the outside options of the financing company are large, as captured by high α and ε. In other words, the lower the value of R's cooperation in the development phase and the lower the loss of surplus if B is diverted to F, the more of a threat of termination R faces. Attractive outside options make it less costly for F to induce R to exert e_N, and the option contract becomes more profitable.

The simple model illustrates that the conflict of research interests between the financing company and the R&D Company may prevent the parties from entering research collaboration

and generating surplus whenever the exact nature of the research activities is not contractible. However, the parties can overcome this problem by assigning the unilateral and unconditional right to terminate to the financing company. The higher the financing company's outside options are, the more likely is it that the option contract is optimal. However, to prevent opportunistic exercise of the option right, payments conditional on termination and continuation need to be specified. Given the financial constraints of the research company and the necessary difference between continuation and termination payments, the financing company may not be able to extract the full profit $\overline{N} - I$. Without introducing financially unconstrained firms formally into the model, we can thus conclude that the use of option contracts covaries with the contractibility of research efforts for financially constrained firms but not necessarily for financially unconstrained firms. If a research company is financially unconstrained, the option contract as well as other, unconditional contracts allows the financing company to extract the full surplus. Thus, the option contract may or may not be employed, regardless of the contractibility of research efforts.

We thus reach three main predictions:

Prediction 1. Option contracts assigning the right to terminate with reversion of broad property rights to the financing company are more likely if research activities are not contractible.

Prediction 2. While research agreements with financially constrained R&D companies employ the termination clause with broad access to the terminated project only if research is non-contractible, research agreements with financially less constrained or unconstrained biotechnology companies may employ either the termination clause or other contract design with or without research contractibility.

Prediction 3. If the research activities of the R&D Company cannot be contracted upon, the higher is the ex-post outside option of the financing company in case of separation from the initial R&D partner, the more likely is it that the research agreement employs an option design with termination and broad rights (conditional on termination) for the financing company.

In the remainder of the paper, we will test these predictions empirically. In addition, we will lie out alternative hypotheses for the correlation between the termination clause with broad rights and non-contractible research efforts. Further empirical tests, which account for variations in uncertainty, in informational asymmetry, in research abilities of the biotechnology company, and in the misalignment of incentives, allow us to distinguish between the model and alternative explanations.

IV. Data

To test how the contractual design responds to variations in contractibility and, in particular, to analyze different explanations for the prevalence of termination rights, we collected a novel data set of research agreements. This section describes how we collected the sample and describes some stylized features about the contract design.

In undertaking this analysis, we sought to employ as large a sample of research agreements between biotechnology companies and commercial partners as possible. These partners are either pharmaceutical companies or other (larger) biotechnology firms. We employed all agreements between 1980 and 2001 that had been analyzed by Recombinant Capital and that met certain criteria discussed below.

Recombinant Capital is a San Francisco-based consulting firm that specializes (since 1988) in tracking contracts in the biotechnology industry. They prepare summaries of the contracts that are marketed directly to parties who are negotiating research agreements and strategic alliances and who are seeking data on comparable transactions. In addition, Recombinant Capital's staff uses their database to prepare comparative studies of particular terms in these agreements. The summaries are based on filings with the U.S. Securities and Exchange Commission (SEC) and other regulatory bodies. The contracts are made public because the publicly traded firms are required by the SEC to file "material documents." Biotechnology companies tend to interpret this requirement conservatively, and often file the contracts specifying alliances as amendments to 10-K, 10-Q, S-1, or 8-K statements. In addition, a number of state governments require privately held companies with employee stock option plans to file "material documents," which are made available to the public. Notice, however, that a large part of the documents thus pertain to publicly traded biotechnology companies rather than early-stage start-up companies. While some information in these agreements is redacted (not made publicly available), Recombinant Capital's staff culls through other SEC filings, news stories, and press releases in order to compile as much data as possible.

We eliminated a number of the summarized transactions in the Recombinant Capital database in an effort to minimize "undesirable" heterogeneity. The eliminated contracts are:

- Research agreements involving universities, medical centers, other non-profit organizations, and government agencies.
- Research agreements where one of the parties had a controlling interest in the other, either through a majority equity stake or through a purchase option (e.g. an alliance between a firm and one of its R&D limited partnerships).

- "Renegotiated agreements," i.e., we excluded cases in which the two parties had a previous research collaboration covering the same set of technologies.
- "Marketing-only agreements" i.e., cases with neither a research nor a product development component.
- Contracts with more than two firms.

While a number of the above sub samples provide interesting variations on the conflict of interest, in particular an exacerbated contrast between scientific and commercial interests in the case of research collaborations with universities, the contract design in these cases varies substantially, mostly reflecting institutional constraints. For examples, many universities require a minimum duration of financial support in order to be able to staff the project and set up other infrastructure. Also, the lack of trade secrets and the higher pressure to publish in universities induce additional caution on the side of the pharmaceutical companies, resulting in more protective contract design. Therefore, we eliminated the above sub samples and ended up with a total of 584 contracts. We carefully examined the contracts and coded the key features of the greatest interest for our analysis (see discussion below).

Table 1 summarizes the contractual features. The research agreements range from 1980 to 2001, with a disproportionate representation of later contracts due to the growth of activity in the industry. The research collaborations range widely in length, averaging about four years.

We will wish to control for the quality of the biotechnology firms in the analyses below. Biotechnology companies may differ substantially in quality: for instance, the seasoning of the key executives and the scientific reputation of the advisors may differ sharply. These differences are difficult to parameterize, though. As a proxy, we will use the reputation of the investment banker who takes the biotechnology firm public: a biotechnology firm underwritten by Morgan Stanley, all else being equal, is likely to be a higher-quality firm than one taken public by D.H. Blair. We determine the ranking of the firm using the ratings compiled by Carter and Manaster (1990), Carter, Dark, and Singh (1998), and Loughran and Ritter (2004). We use the rating that covers the particular time period when the firm went public. If the rating for that period is not available, we employ the rating in the most proximate period.

The focus of our analysis is on the differences in contract design depending on the degree of contractibility of the research activities and (intermediate) research output. To capture such variations in contractibility we examine variations in the condition of the lead product candidate at the time the transaction is signed. Recombinant Capital provides a detailed description of how concretely the main research target is specified. The primary distinction we will make in our analysis is between agreements that build upon a well-defined (contractible) lead product candidate and those where the research program is described in more general terms, without

referring to a specifiable lead product candidate. Our rationale is that in the latter settings (which represent 37.5% of the total), it is hard to specify the exact research tasks and it is therefore least likely that the contractual partners can deal with the cross-subsidization problem directly (in the form of contingent contracting). We would thus expect the use of termination rights with reversion to be more likely in this case.

We relied on the classification scheme of Recombinant Capital to identify contracts with and without a pre-specified lead product candidate. The distinction is rather apparent from the language used in the different types of contract. Lacking a specific compound or process, the contract is less specific and involves a broader "discovery" phase. We illustrate the distinction with a few examples from the "Field of Use" section or preamble of the contract (as specified by Recombinant Capital), which define the scope of the research collaboration. Research agreements that build upon a pre-specified lead product candidate read as follows:

- "*ISIS has discovered ISIS 3521, an antisense oligonucleotide, and is developing a product containing ISIS 3521 for the treatment of cancer... ISIS will use commercially reasonable efforts to complete ongoing clinical trials and studies of the Product for non-small cell lung cancer and non-Hodgkin's lymphoma, as further described in the Development Plan set forth in Exhibit C hereto, and will participate in related activities, including the provision of consulting support to LILLY, in furtherance of the Development Program under the terms and conditions set forth in this Agreement.... "ISIS 3521" means the phosphorothioate oligodeoxyribonucleotide that targets human protein kinase C alpha disclosed and claimed (as SEQ IDNO 2) in U.S. Patent No. 5,703,054.*" (Development and License Agreement, ISIS Pharmaceuticals and Eli Lilly & Co., August 14, 2001.)

- "*The Parties desire to engage in a joint research effort to identify or discover, on the basis of Celgene's lead and library compounds, SERMs which are Er(alpha)Selective in U2OS cells, including, without limitation, compounds in the SP500263 Series (as defined below), as well as analogs thereof made by Celgene prior to the Effective Date as part of its internal research program in the Oncology Field (as defined below) to develop pharmaceutical products from such compounds for the treatment, prevention and diagnosis of osteoporosis and for other indications as described herein... "SP500263 Series" shall mean Celgene's proprietary compounds claimed in U.S. Patent Application Serial No. 09/475,776, filed December 1999 (or any continuation, continuation-in-part or division thereof), including, without limitation, SP500263, SPC0001422 and SPC0001426. The SP500263 Series shall specifically*

exclude Celgene's proprietary compound known as SPC0008490... "U2OS Cells" shall mean (a) Celgene's patent U2OS cell line, (b) Celgene's ER(alpha)-transfected U2OS cell line (clone #: B-11), or (c) Celgene's ER(beta)-transfected U2OS cell line (clone#: 10)." (Collaborative Research and License Agreement, Celgene Corp and Novartis Pharma AG, December 20, 2000.)

Examples of contracts without a pre-specified lead product candidate read instead as follows:

- "*Cubist and Novartis will establish a research program to identify and validate a limited number of antibacterial targets and to develop a select number of validated assays for high-throughput screening to identify new lead compounds active against such validated targets for the development of drugs... Cubist agrees to utilize its proprietary VITA(TM) technology in the Research Program as determined by the Joint Research Steering Committee... which couples the validation of the inhibition of a target in an animal model during an established infection with assay development and screening for the discovery of novel drug leads.*" (Collaborative and License Agreement, Cubist Pharmaceuticals and Novartis, February 3, 1999.)

- "*The goals of the MBI Discovery Program are (a) to identify and characterize Level I Qualified Proteins employing various discovery methodologies, including without limitation secreted protein trapping, genomic cluster mapping and EST sequencing, (b) to identify the therapeutic utility of Program Proteins employing various methodologies, including without limitation transcription expression profiling, animal disease recovery modeling and use of transgenic and knock out models, and (c) to qualify selected Program Proteins for further development by the Parties as Therapeutic Products.*" (Collaboration Agreement, Millennium BioTherapeutics and Eli Lilly & Co., May 28, 1997.)

The level of detail and specificity is much lower in the latter set of contracts. As a result, it is harder to pin down the concrete research tasks to be performed by the biotechnology researchers. In supplemental regressions, we also consider a more narrow definition of contractibility, restricted to projects with a well-defined lead product candidate that has also been tested. The results are little changed.

In Table 1, we also present some summary data on the financial condition of the R&D firm. Most firms have only very modest revenues and financial resources, though there are a few positive outliers.

V. Empirical Analysis

We analyze how the contractual design responds to different degrees of contractibility with particular focus on termination and broad intellectual property rights. We face two choices regarding the nature of the dependent variable used in the analysis. Which provisions should be regarded as indicating whether the financing company had termination and broadened access to the terminated project? And how should the dependent variable be measured?

We wish to determine the extent to which the financing firm was granted the unconditional right to unilaterally terminate the agreement and obtain the rights to the product upon termination. While a wide variety of clauses allow the financing firm to terminate the agreement, most of those are conditional on specific events, such as bankruptcy or acquisition of the R&D company. To capture contractual remedies that are based on non-verifiability information, we focus on cases where the financing firm can terminate the agreement without a clear trigger. Three cases appeared in the agreements we reviewed that met our criteria:

- When the financing company can terminate the agreement for any cause, either within a defined time period (e.g., after one year of the agreement's signing) or at any stage of the research collaboration.
- When the financing firm can terminate the research collaboration for "misbehavior" or "breach" of the agreement.
- When the financing company believes the continuation of the research collaboration would be "unwise."

Note that, in theory, the second termination criterion differs from the others. When a party terminates because of "breach" a court may later find it to be the actual breaching party. With the other two termination provisions, this is almost impossible; no court would second-guess a firm's decision to terminate because continuing was "unwise." As a practical matter, however, the termination right for "material breach" enables the terminating party to move forward with various self-help remedies unless and until the other party goes to court to litigate the issue. In addition, the burden is then on the non-terminating party to show the termination was not justified. Thus, these provisions give the terminating party the right to act unilaterally. Especially

when the other party is a cash-constrained biotechnology company, it is practically the equivalent of an open-ended termination right like the first and third ones listed.[17]

As noted in Table 1, termination rights appear to be a widespread feature of contracts. In almost all contracts some kind of termination right is specified (97.7%) and is assigned to the financing company or both parties (96.7%). More than half of those termination rights are conditional on specific events, while about 39% of the research agreements have provisions for the financing firm to terminate the collaboration unconditionally. In 11%, the financing firm has both termination rights and broad access to the intellectual property after the termination of the agreement.

As the theory above suggests, we are interested in contractual provisions that exclude the R&D company from retaining all the value generated during the collaboration if the research collaboration is terminated. This is the case when the intellectual property rights revert to the financing company. Arguably, patents and other intellectual property rights are worth less in the hands of the financing company, and thus should be always assigned to the R&D company if the collaboration is successful. However, the threat of reversion enables the financing company to ensure profit-maximizing research efforts on the part of the R&D researchers. We identify all situations where the financing company retains rights to the intellectual property employed in the research alliance after its termination. The interaction between this dummy variable and the four-part measure of termination rights will be the primary dependent variable in our analysis.

We construct the dependent variable in several ways. We use both a simple binary variable, which takes the value of one if the financing company has at least one unconditional termination right (along with broadened rights), and a more refined integer variable, which accounts for the number of termination rights of the financing company. In the latter case the dependent variable takes on measures from zero to +3. Furthermore, in light of alternative explanations for the right to terminate, both on the side of the financing company and the R&D company, we consider only cases where the financing company has the right to terminate (with broad rights) and the R&D company has no right to terminate (with or without broadened rights). Again, we construct both the simple binary variable, which takes the value of one if the financing company has at least one termination right and the R&D company has none, and as well as integer variables with values from –3 to +3, counting the "net" termination rights of the financing company minus those of the R&D company. All approaches deliver approximately the same results.

We begin by testing Prediction 1. We examine the extent to which projects without a contractible lead product candidate at the time the research agreement is signed are more likely to

[17] For a discussion of some of these issues in a recent licensing case, see Judge Easterbrook's opinion in *Baldwin Piano Inc. v. Deutsche Wurlitzer GmbH*, 73 USPQ2d 1375 (CA 7 2004).

grant the financing company the right to terminate the collaboration while obtaining broad access to the intellectual property involved.

In Table 2, we present a series of cross-tabulations. In Panel A, we undertake simple univariate comparisons. When there is no specifiable lead product candidate at the time the alliance is signed, the agreement is significantly more likely to assign termination and broad rights to the financing firm. This is also likely to be the case when the agreement is between two biotechnology firms.

In Panel B, we undertake a series of cross-tabulations. We show that the differences between projects where there is no specifiable lead product is only statistically significant when the firm is ranked above the median of biotechnology firms in terms of underwriter reputation, the agreement is between two biotechnology firms, and the R&D firm's financial condition is below the median. As we will argue below, these results are consistent with theoretical predictions.

We now turn to econometric analyses. The baseline regression analysis is reported in Table 3. We employ a variety of control variables:

- We are concerned that there may be a time trend in the transactions, so we control for the date of the agreement. In the initial regressions, we employ a continuous date variable; in supplemental regressions, we use dummy variables for each year.
- Diagnostic and veterinary products are likely to face a substantially different information environment from therapeutic products. Not only are the scientific uncertainties often significantly reduced for a diagnostic product, but also the regulatory hurdles for both classes of products are considerably reduced.
- The cross-subsidization problems may be more severe if the biotechnology firm holds large number of patents, indicating numerous related research avenues. We identify in U.S. Patent and Trademark Office databases all patent awards to the biotechnology firm at the time the alliance is signed.
- Capital constraints may affect the transactions that the parties reach. In the baseline regression, we control for the amount of time the firm has until it runs out of cash. In particular, we take the absolute value of the ratio of the firm's current cash flow to its cash in hand ("cash burn rate"). If the firm has positive cash flow, we code this measure as zero. A higher value implies that it is sooner until the firm runs out of money.
- Previous research agreements may ease the contracting between the two firms. In particular, the reputational capital that the two parties built up in previous alliances may allow firms to overcome problems that would be difficult to contract around if the parties suspected each other of being opportunistic.

The table presents a number of regressions, which use some or all of these independent variables. In addition, we employ both ordinary least squares and ordered logit specifications, which may better reflect the ordinal, non-negative nature of the dependent variable. Finally, we employ fixed effects for each year instead of the continuous date variable.

Across the reported regressions—and the many dozens of similar though unreported analyses—we find a consistent pattern. Research collaborations that encounter considerable contracting difficulties at the time that the transaction is signed are associated with a substantial boost in the probability of broadened property rights and termination rights being assigned to the financing firm. This result is not only statistically, but also economically significant: the average coefficient across the four ordinary least squares regressions of 0.11 is significant relative to the mean of the dependent variable (0.15).[18]

A natural concern in this analysis has to do with endogeneity. For instance, a major issue affecting the entire empirical literature on (research) alliances is the (endogenous) choice to enter an alliance. The pharmaceutical companies entering into research alliances are likely to be different from those not entering alliances. These differences may affect the observed contract design. While there is no obvious reason why the endogenous entry decision would affect the empirical results reported above, we attempt to address at least part of the selection issue. In particular, we would like to make sure that our results are not driven by endogenous matching between low-ability research types and pharmaceutical companies who (opportunistically) insist on termination rights.

To address this possibility, we employ fixed effects for the 13 most frequently represented pharmaceutical companies in Table 4, thus holding the type of pharmaceutical companies constant. When we employ a variety of specifications, we still find a consistently strong relationship between the difficulty of contracting and the assignment of termination and broad intellectual property rights to the financing firm. The addition of the pharmaceutical company dummy variables has little impact on the other coefficients. These results suggest that, for a given pharmaceutical company, the variation in termination and reversion rights is indeed related to the research program. The results also alleviate partly the larger endogeneity concerns pointed out before. The occurrence of different types of contracts within the same pharmaceutical firm ensure that our results are not driven by the fact that certain types of companies only enter research agreements with specified lead-product candidates, while other types of companies only enter those without.[19]

[18] The R^2 is comparable to other empirical studies analyzing non-standardized contracts, Robinson and Stuart (2004).

[19] In unreported analyses, we repeat the regressions, clustering the standard errors in the analyses by pharmaceutical company. This modification has little impact on the results.

Additional predictions

We now turn to examining the two additional predictions of our theory, relating to the impact of financial constraints and outside options.

Financial constraints. We first test Prediction 2 and examine the impact of financial constraints on the contract design. As noted in the introduction, our paper—in a manner similar to Aghion and Tirole (1994)—suggests that the financial constraints of the biotechnology firm (the research unit, in their parlance) may preclude arriving at the first-best outcome. We should thus anticipate that the relationship between the assignment of termination and broad intellectual property rights to the larger firm and a non-contractible lead product candidate should be stronger among financially constrained firms.

The assumption that the biotechnology company faces financial constraints, implicit in the above theoretical analysis, is certainly appropriate for the vast majority of biotechnology companies. Our sample of biotechnology firms is peculiar, however, in that many firms have undergone an initial public offering and are thus relatively large and established firms. As a result, many of the biotechnology firms in our sample are not subject to financial constraints to the same extent as a typical biotechnology start-up company. Since the systematic correlation between the assignment of termination and revision rights to the financing firm and a non-contractible lead product candidate depends on the presence of financial constraints, we now test whether this dependence is borne out in the data: i.e., whether our results are driven by contracts with those biotechnology firms that are (most) financially constrained.

To identify biotechnology firms that are capital constrained, we employ several simple approaches. In the reported regressions in Table 5, we divide the firms based on their net income in the year prior to the research collaboration being formed and cash and equivalents at the end of that year. (We employed a similar approach in the cross-tabulations reported in Table 2, which corroborated the predicted pattern.) Cases where the biotechnology firm has net income or revenue above and below that of the median firm (in 2002 dollars) are considered separately. We find that consistent with our hypothesis, firms that are below the median along these measures are the only ones that display a statistically significant relationship between the provisions of broad intellectual property and termination rights to the financing firm and projects that are especially difficult to contract upon. In research alliances where the parties were above the median on these measures, the coefficient on this variable is roughly half the size and not statistically significant.

In unreported regressions, we explored the robustness of these results to other divisions of the firms. In this analysis, our choice of the median to divide firms was somewhat arbitrary: it is not obvious where capital constraints will become severely binding. It appeared that the results became even sharper when we isolated even more extremely constrained subsets of firms. For

instance, the differences are more dramatic when we employ the bottom quartile of firms in terms of net income and cash and equivalents.

Outside options. We then turn to testing whether higher ex-post outside options of the pharmaceutical company in case it owns the patents make the option contract more attractive, and thus more frequently employed in contractually difficult environments. We hypothesize that, while pharmaceutical companies are less likely to gain from broader rights – all they are interested in is the license to the specific product allowing for production and sales – other biotechnology firms may benefit more from these rights. Those biotechnology companies that have grown large and enter research collaborations with other (typically much smaller) biotechnology companies in the role of the financing parties are likely to have more research capacity to use the patents for future projects, even without the collaboration of the original contract partners. In terms of the model, α is likely to be large.

We thus split up our sample into research agreements between a pharmaceutical company and a biotechnology company and those between two biotechnology firms. Our data set contains 77 cases of research agreements between biotechnology companies and 453 cases of research agreements between a biotechnology and a pharmaceutical company.[20] We rerun the regression of Table 3 on those two sub-samples (Table 6). We find that the effect of a non-specifiable lead product on option contract design is much larger and, despite the smaller sample size, considerably more precisely estimated in the sample of contracts between biotechnology firms. This result—which is consistent once again with the cross-tabulations in Table 2—confirms Prediction 3 of our model.

In Table 7, we take another approach, estimating pooled regressions that include all observations. We first repeat the financial constraints analysis. We include separate dummy variables for R&D firms that are above and below the median net income, as well as interactions between these dummies and an indicator of whether there was no specifiable lead product candidate at the time the research agreement was signed. Only the interaction term indicating projects where the R&D firm is financially constrained and the project is not specifiable proves to be significantly positive.

In the second column of Table 7, we repeat the analysis in Table 6, now pooling the observations. We again employ dummy variables for agreements that are and are not between two biotechnology firms, as well as interactions with an indicator of whether there is a no specified

[20]In the regressions in Table 5, the sample size in one regression is always relatively modest (either due to the low number of biotechnology-biotechnology agreements or the "lumpiness" in the underwriter rank measure). As a result, we estimate these regressions without three of the additional control variables. The results are quite similar, however, when we do employ these controls, though the sample size shrinks considerably.

lead product candidate at the time of the signing of the agreement. Once again, only the coefficient on the variable denoting the agreements between biotechnologies companies without a specified lead product candidate proves to be statistically significant.

Alternative explanations

Our proxy for contractibility is, naturally, noisy and leaves room for a number of alternative explanations. In this section, we consider what we believe to be the three main alternative interpretations of the observed contract design.

Research abilities of the biotechnology company. The contract design may be related to uncertainty or asymmetric information about the "type" of the biotechnology company. When entering the research collaboration, the financing company cannot perfectly assess the abilities of the biotechnology researchers with respect to the joint project and the chances of a successful collaboration. Termination rights allow the financing company to end the relationship as soon as it has recognized the biotechnology partner to have relatively low ability. For this story to explain our results, the "unspecified lead product" variable would need to capture higher uncertainty about research abilities or collaboration success.

For two reasons, however, this adverse-selection story is an unlikely explanation for the observed variations in contract design. First, we attempt to control for the research abilities directly. To do this, we examine the underwriter who took the biotechnology firms public. We anticipate that those firms that went public with the highest quality underwriters are likely to be higher quality than those that did not. Following previous literature, we use a Carter-Manaster (1990) style score to proxy for underwriter reputation. Table 3 indicated already that our results are independent of this control. In addition, we run separate regressions for firms ranked above and below the median on their Carter-Manaster (1990) score. We find in Table 8 that the effects are much stronger among the high-quality firms, i.e., among the biotechnology firms that went public with the best underwriters. (Again, this result is consistent with the cross-tabulations above.) The result runs against the alternative hypothesis delineated above. If the difficulty of discerning the R&D firm's type were the critical consideration behind the use of these provisions, we might anticipate that the relationship between the assignment of termination and broader intellectual property rights to the financing firm and difficulty of contracting would be instead stronger among the lower-reputation firms. Moreover, the above-median firms are not only likely to have higher abilities and better prospects, but should also benefit from the "certification" of their research abilities that is implicit in the underwriter quality. The high reputation rank of their underwriter should thus reduce the uncertainty about their "type" and render the termination and

broader access rights more dispensable. The empirical results of Table 3 suggest, however, that these considerations do not trigger the analyzed contractual clauses.[21]

Second, this story lacks a reason why the pharmaceutical company should also want to obtain broader rights. Quite to the contrary, intellectual property produced by "low research types" is likely to be least attractive to the pharmaceutical company. In other words, for this alternative explanation to hold, our results would need to be driven by the termination right, and not by the broad intellectual property rights. To distinguish between this alternative and the incomplete-contracts hypothesis, we repeat the analysis above, now using a dummy denoting whether the pharmaceutical company has the right to terminate the agreement (again coded as 0 to +3) as the dependent variable, but without the interaction with the measure of broad intellectual property rights. We find in the first four columns of Table 9 that under various specifications, the difficulty of contracting has no significant impact on the assignment of termination rights by themselves.

Variations in uncertainty, informational asymmetry, or incentive misalignment. The contractibility hypothesis put forward in this paper builds on misaligned research incentives and non-contractibility of research effort. We attribute the variation in contractual termination and reversion clauses to variations in contractibility, holding incentive conflicts, informational asymmetry, monitoring costs, *etc*. constant. Alternatively, variations in the latter variables may determine the implementation of termination and reversion rights. For instance, the parties may employ termination and broad intellectual property rights whenever they are facing higher uncertainty about the outcome, or whenever the informational asymmetry between pharmaceutical and biotechnology company is higher, or whenever the incentive conflict between the parties is higher. Any of these alternative suggestions would build on a model where termination and broad rights help to solve the incentive problem, but do so at a cost. The cost may be lower profit extraction for the pharmaceutical company (due to financial constraints of the biotechnology firm). Or it may be the risk of opportunistic exercise of the termination right on the side of the pharmaceutical company. Then, the termination and broader rights are employed only if the incentive problem is "severe enough," i.e., if uncertainty, informational asymmetry, or the incentive misalignment are big enough.

Before we present additional results that attempt to distinguish between the alternative explanations and our hypothesis, it is noteworthy that all of these stories need contractual incompleteness as a key ingredient. If the parties could write contracts on the exact action to be

[21] While these results allow us to reject the alternative hypothesis, they raise the question as to why this relationship should be stronger among the high-quality firms. One possibility is that the observations of firms with lower-quality underwriters are much noisier. Endogenous selection may lead to only "safe" (contractible) cases being contracted.

taken by the biotechnology researchers or condition on all possible outcomes, termination rights would not be employed since they come at a cost relative to writing complete contracts. Thus, even under these alternative explanations our results provide evidence on the impact of contract design when actions or outcomes are non-contractible.

However, additional empirical results cast some doubt on these alternative hypotheses. One first indicator that variations in uncertainty or informational asymmetry are unlikely to drive all of our results is the regressions that control for the type of research program (therapeutic, diagnostic, and veterinary). As noted above, the scientific and regulatory uncertainty is substantially higher for the development of therapeutic products. Nevertheless, we do not find a consistent, significantly positive correlation between the termination and reversion clauses and therapeutic products. Moreover, even if we eliminate undesired heterogeneity in uncertainty and we examine only agreements focusing on therapeutic products, our baseline results go through as before, with a coefficient of 0.11 (and a standard error of 0.05)[22]

What may be related to uncertainty and informational asymmetry is the termination right per se, not bundled with broad intellectual property rights. In the first four columns of Table 9, where we analyze "termination rights only" as the dependent variable, we find no relation between unspecified lead product candidate and termination rights. However, we also find that termination rights are negatively related to diagnostic and veterinary products. To the extent that the parties face less uncertainty with these types of products or less informational asymmetry about the prospects of the research program, the table indicates that other types of termination clauses may well be driven by variations in uncertainty. At the same time, these "non-results" help us feel comfortable that the results on the termination rights with broadened rights do not simply stem from the fact that the pharmaceutical company just learns the type of the biotechnology company over time.

In the last two columns of Table 9, we also undertake a regression analysis employing *specified* termination provisions: that is, those triggered by distinct events. We focus on four classes of provisions: those triggered by the bankruptcy of one of the firms, change in control of one of the firms, the termination of another agreement by one or both of the parties, and other pre-specified events. As before, we employ as the dependent variable the interaction between a count of the number of provisions present (between zero and four) and a dummy variable that takes on the value one if intellectual property reverts (at least in part) to the financing firm. Since our predictions are specific to the combination of unconditional termination rights and broad

[22]When we focus on diagnostic and veterinary products, however, there is no meaningful relationship between the difficulty of contracting and the assignment of termination and broad intellectual property rights to the financing firm. The latter result may either be due to the small sample size (less than one-fifth of the observations fall into either of these categories) or because researchers of the pharmaceutical company can closely monitor and direct the research activities.

intellectual property rights, we would like to make sure that not "any" of the other termination rights, combined with broader rights, have a similar correlation with the nature of the research program.

The results are quite different from those in the earlier tables. In transactions without a specified lead product at the time the agreement is signed, there is no significant tendency for these termination and reversion rights to be more frequently assigned to the financing firm. This result is again consistent with our hypothesis: the termination and broad intellectual property rights are a substitute for conditional contracting.

The above results address uncertainty and informational asymmetry. As mentioned before, one may also attribute the correlation between termination rights with broader access to the intellectual property and lead-product specification to variations in the degree of incentive conflict. In other words, research programs with an unspecified lead product candidate are more likely to imply different research interests than those for which the parties have agreed on a candidate. Based on our conversations with practitioners, however, the opposite appears to be the case. A biotechnology company that enters a research agreement with a pre-specified and potentially even tested product candidate is more likely to be involved in parallel research collaborations and simultaneous, related research projects, increasing rather than decreasing the scope for project cross-subsidization. In other words, while it is harder to control project cross-subsidization in research collaborations without a specified lead product candidate, the prospect for cross-subsidization may in fact be smaller.

Bargaining power. Another alternative explanation for the contracting pattern analyzed above is the relative bargaining power of the two parties. Biotechnology firms without well-developed and thus specifiable products may be less able to resist the demands of prospective partners for strong control rights.

We cannot observe the bargaining power of the two parties, and thus cannot reject this possibility with absolute certainty. We believe that the evidence presented above, however, is inconsistent with this alternative explanation. Most convincing is the analysis presented in Table 3 (and in similar unreported regressions). If unobserved differences in bargaining power were behind the seeming importance of the "No specifiable lead product at the time of the signing of the research agreement" variable, then we would anticipate that the addition of more control variables would lead to the coefficient's magnitude and significance falling. Control variables, such as the number of patents of the biotechnology firm, its financial strength, and the number of other research alliances, should at least partially capture variations in the bargaining power of the biotechnology company, and thereby reduce the partial correlation between the "No specifiable lead product" variable and the unobserved bargaining power. However, quite the opposite occurs:

as we add independent variables that should be correlated with bargaining power, the magnitude and significance of the "No specifiable lead product" actually *increases*. This pattern continues to hold when we add independent variables measuring the biotechnology firm's financial condition and patent holdings in greater detail, as well as the financing environment for biotechnology firms more generally. The failure of these variables to reduce the explanatory power of the key independent variable leads us to reject this alternative explanation.

VI. Conclusion

Overall, the empirical evidence on contract design in biotechnology research agreements provides an example of firms reacting to limited contractibility by designing decision rights and combining these with payments conditional on the exercise of the decision right. Our approach differs from the previous empirical literature following the property-rights approach in that we focus on a property right different from the allocation of asset ownership; in fact, it appears, that the parties endogenously "generate" a decision right to solve the problem of contractual incompleteness.

At the same time, part of the contribution of this paper is that we shed light on the nature of the incentive and contracting problem in research alliances, in particular the problem of project substitution or project cross-subsidization. Moreover, we provide new details on the contractual design in research agreements, which are consistent with the theory proposed in this paper, but which also may be of interest for a better understanding of inter-firm organizations.

To be sure, the right to terminate is only one of a complex array of decision rights inherent in research collaborations. Moreover, there may well be other empirical approaches to testing the theoretical hypotheses in this paper: for instance, examining the shifting terms of agreements that are renegotiated. But the analysis suggests the promise of combining theoretical and empirical approaches to understanding contract design.

Appendix A. Notation of Model

R	Research company (typically biotechnology company)
F	Financing company (typically pharmaceutical company)
t	Time period in the model (0, 1, 2 and 3)
I	Initial investment, required to generate any research surplus
e_N	"Narrow" research effort by R
e_B	"Broad" research effort by R
N	Expected narrow surplus, i.e., profits from product targeted in the collaboration.
$\overline{N}$	High value of expected narrow surplus, resulting from narrow research effort.
$\underline{N}$	Low value of expected narrow surplus, resulting from broad research effort.
B	Expected broad surplus, i.e., profits from other products and, for R, value of entering collaborations with other firms.
$\overline{B}$	High value of expected broad surplus, resulting from broad research effort.
$\underline{B}$	Low value of expected broad surplus, resulting from narrow research effort.
ε	Share of B that F can capture if it has the rights for the broad research.
α	Share of N that F can capture without the collaboration of the original research partner R if F has the rights for the narrow research.
p_T	Payment from F to R conditional on termination
p_C	Payment from F to R conditional on continuation
Δ	$(1-\alpha)\underline{N}-\varepsilon\overline{B}$
Γ	$(1-\alpha)\overline{N}-\varepsilon\underline{B}$

Appendix B.

Proof of Lemma 4.

We consider separately option contracts with $i = F$ and with $i = R$. For the class of all option contracts with $i=F$, we first show that F's payoff Π_O from any option contract that does not both (i) induce continuation in equilibrium and (ii) allocate at least the narrow rights to F after continuation is weakly smaller than Π^*_{NO} or strictly smaller than $\hat{\Pi}_O$.

For the set of contracts violating (i), i.e., inducing termination in equilibrium, we distinguish four cases.

If $o_T = \varnothing$, then $\Pi_O = -p_T - I < 0 \leq \Pi^*_{NO}$ (given $p_T \geq 0$).

If $o_T = B$, then $\Pi_O = \varepsilon B - p_T - I$ where R's participation constraint implies $p_T \geq \underline{B}$ and thus (with A.3) $\Pi_O < 0 \leq \Pi^*_{NO}$.

If $o_T = N$, then $\Pi_O = \alpha N - p_T - I \leq \alpha N - I < \hat{\Pi}_O$.

If $o_T = N + B$, then $\Pi_O = \alpha N + \varepsilon B - p_T - I$ where R's participation constraint implies $p_T \geq \underline{B}$ and thus (with A.3) $\Pi_O < \alpha N - I < \hat{\Pi}_O$.

For the set of contracts satisfying (i) but violating (ii), i.e. inducing continuation in equilibrium but not allocation of the narrow rights to F, we distinguish two cases.

If $o_C = \varnothing$, then $\Pi_O = -p_C - I \leq 0 \leq \Pi^*_{NO}$.

If $o_C = B$, then $\Pi_O = \varepsilon B - p_C - I$, where R's participation constraint implies $p_C \geq \underline{B}$ and thus $\Pi_O < 0 \leq \Pi^*_{NO}$.

This leaves two types of contracts, which satisfy both (i) and (ii): contracts inducing continuation and allocating both broad and narrow rights to F after continuation $(o_C = B + N)$, and contracts inducing continuation and granting narrow rights after continuation $(o_C = N)$. Contracts with $o_C = N + B$, however, have to satisfy the following four constraints: (a) The participation constraint for R is $p_C \geq \underline{B}$. (b) The incentive-compatibility constraint ensuring that F continues after R exerted e_N is

$$p_C - p_T < \begin{cases} \overline{N} + \varepsilon \underline{B} & if\ o_T = \varnothing \\ \overline{N} & if\ o_T = B \\ (1-\alpha)\overline{N} + \varepsilon \underline{B} & if\ o_T = N \\ (1-\alpha)\overline{N} & if\ o_T = B+N \end{cases}$$

(c) The contract also needs to satisfy incentive-compatibility for F to terminate after e_B. Otherwise R would choose e_B instead of e_N, given A.1.

$$p_C - p_T \geq \begin{cases} \underline{N} + \varepsilon \overline{B} & \text{if } o_T = \varnothing \\ \underline{N} & \text{if } o_T = B \\ (1-\alpha)\underline{N} + \varepsilon \overline{B} & \text{if } o_T = N \\ (1-\alpha)\underline{N} & \text{if } o_T = B+N \end{cases}$$

(d) The incentive-compatibility constraint ensuring that *R* chooses e_N is

$$p_C - p_T > \begin{cases} \overline{B} & \text{if } o_T = \varnothing \\ 0 & \text{if } o_T = B \\ \overline{B} & \text{if } o_T = N \\ 0 & \text{if } o_T = B+N \end{cases}$$

An equilibrium exists, i.e., all four conditions are satisfied if

$$\begin{aligned} &\overline{B} < \overline{N} + \varepsilon \underline{B} \quad \text{and} \quad \overline{N} - \underline{N} > \varepsilon(\overline{B} - \underline{B}) && \text{for } o_T = \varnothing \\ &\underline{B} < \overline{N} && \text{for } o_T = B \\ &\overline{B} < (1-\alpha)\overline{N} + \varepsilon \underline{B} \quad \text{and} \quad (1-\alpha)\overline{N} > (1-\varepsilon)\underline{B} && \text{for } o_T = N \\ &\underline{B} < (1-\alpha)\overline{N} && \text{for } o_T = B+N \end{aligned}$$

In these cases, the maximization problem of *F* amounts to minimizing p_C under the above participation constraint and incentive compatibility conditions. We can characterize the optimal p_C^* (if it exists) as follows:

$$p_C^* \geq \begin{cases} \max\{\overline{B}, \underline{N} + \varepsilon \overline{B}\} & \text{for } o_T = \varnothing \\ \max\{\underline{B}, \underline{N}\} & \text{for } o_T = B \\ \max\{\overline{B}, (1-\alpha)\underline{N} + \varepsilon \overline{B}\} & \text{for } o_T = N \\ \max\{\underline{B}, (1-\alpha)\underline{N}\} & \text{for } o_T = B+N \end{cases}$$

It is easy to check that the payoff $\Pi_O = \overline{N} + \varepsilon \underline{B} - p_C^* - I$ is smaller than $\hat{\Pi}_O$ in all four cases, even if we set p_C^* equal to its lower bound.

It remains to be shown that contracts with $o_C = N$ but $o_T \neq N + B$ do not yield a higher or equal payoff for *F* than the contract considered in Lemma 2 ($o_C = N, o_T = N + B$). Note first that $o_C = N$ implies that the participation constraint for *R* is not binding since *R* receives the broad surplus. The incentive compatibility constraint ensuring that *F* continues after e_N is

$$p_C - p_T < \begin{cases} \overline{N} & \text{for } o_T = \varnothing \\ \overline{N} - \varepsilon \underline{B} & \text{for } o_T = B \\ (1-\alpha)\overline{N} & \text{for } o_T = N \end{cases}$$

The contract needs to induce *F* to terminate if *R* chooses e_B; otherwise *R* would choose e_B over e_N and receive $\overline{B} + p_C > \underline{B} + p_C$. The incentive compatibility constraint for *F* is thus

$$p_C - p_T \geq \begin{cases} \underline{N} & \text{if } o_T = \varnothing \\ \underline{N} - \varepsilon \overline{B} & \text{if } o_T = B \\ (1-\alpha)\underline{N} & \text{if } o_T = N \end{cases}$$

and the incentive compatibility constraint ensuring that R chooses e_N is

$$p_C - p_T > \begin{cases} \overline{B} - \underline{B} & \text{if } o_T = \varnothing \\ -\underline{B} & \text{if } o_T = B \\ \overline{B} - \underline{B} & \text{if } o_T = N \end{cases}$$

The resulting conditions for existence are

$$\overline{B} - \underline{B} < \begin{cases} \overline{N} & \text{if } o_T = \varnothing \\ (1-\alpha)\overline{N} & \text{if } o_T = N \end{cases}$$

In these cases or for $o_T = B$, the maximization problem of F amounts to minimizing p_C under the above p_C incentive compatibility constraints and yields the solution

$$p_C^* = \begin{cases} \max\{\overline{B} - \underline{B}, \underline{N}\} & \text{for } o_T = \varnothing \\ \underline{N} - \varepsilon \overline{B} & \text{for } o_T = B \\ \max\{\overline{B} - \underline{B}, (1-\alpha)\underline{N}\} & \text{for } o_T = N \end{cases}$$

and the resulting payoff $\Pi_O = \overline{N} - p_C^* - I$ is smaller than $\hat{\Pi}_O$ in all three cases.

Thus, we have shown that there is no option contract with $i = F$ and a payoff Π_O such that $\Pi_O > \Pi_{NO}^*$ and $\Pi_O \geq \hat{\Pi}_O$.

Finally, consider the class of contracts where R has the right to terminate. Contracts that do <u>not</u> (i) induce continuation in equilibrium and (ii) allocate narrow rights to F after continuation are ruled out the same way as for $i = R$. Further, contracts satisfying (i) and (ii) allocate at least narrow rights after continuation and will thus always induce R to choose e_B since R's payoff after continuation if choosing e_N is always weakly (for $o_C = N + B$) or strictly (for $o_C = N$) smaller than if choosing e_B. However the maximum payoff resulting from any contract inducing R to choose e_B is Π_{NO}^*. Thus, there is also no option contract with $i = R$ and payoff Π_O satisfying $\Pi_O > \Pi_{NO}^*$ and $\Pi_O \geq \hat{\Pi}_O$. **Q.E.D.**

Appendix C. Renegotiation

The results in Section III have been derived under the assumption that the parties can commit not to renegotiate. We now allow for renegotiation of the original contract after period 1. As in Nöldeke and Schmidt (1995), we assume that, at one point in time between periods 1 and 2, both R and F can send signed offers to each other, specifying new prices $\tilde{p}_C$ and $\tilde{p}_T$ as well as a new (conditional) allocation of property rights. After F has decided whether to continue or to

terminate at time 2, the parties can both present any signed offer they received in court. The court can observe whether F initiated termination or not and will enforce the respective payment as specified in the original contract unless

- exactly one party presents a signed renegotiation offer from the other party to the court
- both sides present the same renegotiation offer to the court.

In those two cases, the court enforces the renegotiated contract. We assume that

(A.5) R and F are willing to accept the best renegotiation offer received from the other party if their own equilibrium payoff in the continuation game (after $t = 1$) under the renegotiated contract is weakly larger than the equilibrium payoff under the original contract. They are willing to make a renegotiation offer if their renegotiated equilibrium payoff in the continuation game is strongly larger than the original equilibrium payoff.

For example, if R exerts e_B and F does not send any signed offers to R but R sends a signed offer, F will accept R's offer if the resulting equilibrium allocation of surplus to F is at least as high as the equilibrium payoff under the original contract. We apply the concept of sub game-perfect equilibrium. Given this renegotiation mechanism, we can specify when the contract derived in Lemma 2 is renegotiation-proof.

Lemma 5. *For* $\Delta \geq 0$*, contracts in* $\hat{A}_O$ *are not renegotiation-proof. For* $\Delta < 0$*, contracts in* $\hat{A}_O$ *with* $p_T < -\Delta$ *are renegotiation-proof.*

Proof. We first determine in which subgames, after R has chosen e, renegotiation may occur. In any subgame following effort choice e_N, the original contract allows for extraction of the full surplus, with expected value $\overline{N} + \underline{B}$. Any reallocation is either a mere transfer or reduces the total surplus. Both parties can guarantee themselves the payoff resulting from the original contract by not making any renegotiation offers and not presenting any offers they receive. Thus, there is no scope for renegotiation. In any subgame following effort choice e_B, the surplus under the original contract, $\alpha\underline{N} + \varepsilon\overline{B}$, is smaller than the surplus that can be extracted if F does not terminate. Hence, there is scope for renegotiation-inducing continuation. (Since the original contract recommends termination in the sub-game, any other contract that leads to termination is a mere transfer.)

We now show that a necessary condition for R to exert e_B and for subsequent renegotiation to succeed after e_B is that R offers a new contract. Suppose, instead, that R exerts e_B, but does not make a renegotiation offer. If F makes an offer, F will allocate an equilibrium continuation

payoff of exactly p_T to R since this suffices to induce R to accept the offer (with A.5). Anticipating this, R will exert e_N instead of e_B to ensure a renegotiation-proof payoff of $\overline{B} + p_C = \overline{B} + \max\{0, \Delta\}$, which is strictly larger than p_T for all subcases specified in Lemma 2. This contradicts the initial assumption that R exerts e_B. Successful renegotiation thus requires R to make an offer.

With assumption A.5, two conditions need to be satisfied to induce R to choose e_B and to make a renegotiation offer upon which F continues and which F would enforce:

1. Conditional on R choosing e_B, F's payoff after continuation and enforcing R's renegotiation offer is weakly higher than F's payoff after termination and enforcing the original contract.
2. Given F's equilibrium strategies in the continuation games, R's payoff after e_B and continuation under the renegotiated contract is strictly higher than after e_N and continuation under the original contract.

We consider separately renegotiation offers that (re-)assign (i) both broad and narrow rights and (ii) only narrow rights to F upon continuation.

(i) *Broad and narrow rights*. In order to accept R's renegotiation offer and to choose continuation, F requires a continuation payoff $\underline{N} + \varepsilon\overline{B} - \widetilde{p}_C$ that is weakly higher than the continuation payoff after termination under the original contract, $\alpha\underline{N} + \varepsilon\overline{B} - p_T$. The resulting upper bound of $\widetilde{p}_C$ is $\widetilde{p}_C \le (1-\alpha)\underline{N} + p_T$. Thus, R can at most ensure a payoff of $(1-\alpha)\underline{N} + p_T$ instead of $\overline{B} + p_C$ under the original contract. It is easy to check that, for all three subcases specified in Lemma 2, R's continuation payoff under the original contract is strictly higher. Hence, R will not choose e_B and then make a renegotiation offer allocating both the narrow and the broad rights to F in case of continuation.

(ii) *Narrow rights*. F accepts R's renegotiation offer and chooses continuation if the continuation payoff $\underline{N} - \widetilde{p}_C$ is weakly higher than the continuation payoff after termination under the original contract, $\alpha\underline{N} + \varepsilon\overline{B} - p_T$, i. e. if $\widetilde{p}_C \le (1-\alpha)\underline{N} - \varepsilon\overline{B} + p_T$.

For $\Delta < 0$, we can find such a $\widetilde{p}_C$ only if the original p_T was set equal to $-\Delta$ (given the non-negativity constraint). Thus, by choosing $p_T < -\Delta$ (within the ranges specified in Lemma 2), F avoids renegotiation, induces R to exert e_N, and obtains the resulting higher payoff.

For $\Delta \ge 0$, any $\widetilde{p}_C \in [0, \Delta]$ satisfies the above condition and the non-negativity constraint. Conditional on having chosen e_B, R will thus make a renegotiation offer, proposing the highest possible $\widetilde{p}_C$, i.e., $\widetilde{p}_C = \Delta$, and receive $\overline{B} + \Delta$. Moreover, R prefers choosing e_B and renegotiating to choosing e_N, since $\overline{B} + \Delta > \underline{B} + \Delta$. **Q.E.D.**

Lemma 5 immediately implies that for $\Delta < 0$, where $\hat{\Pi}_O > \Pi^*_{NO}$ (Lemma 3), F will offer a contract from the set $\hat{A}_O$ with $p_T < -\Delta$. Similarly, for $\Delta \geq \overline{N} - \max\{\underline{N}, I\}$, where $\hat{\Pi}_O \leq \Pi^*_{NO}$ (Lemma 3), F will offer a (renegotiation-proof) contract from the set A^*_{NO}. It remains to be shown which contract generates the highest payoff for F in the range $0 \leq \Delta < \overline{N} - \max\{\underline{N}, I\}$. We focus on the choice between renegotiation-proof contracts in A^*_{NO} and option contracts (F, p_C, p_T, N, $N + B$) satisfying (1), i.e., inducing e_N in a setting without renegotiation.

Denote with $\tilde{\Delta}$ the maximum of $\alpha\overline{N} + \varepsilon\underline{B}$, $\underline{N}$, and I, i.e., $\tilde{\Delta} = \max\{\alpha\overline{N} + \varepsilon\underline{B}, \underline{N}, I\}$. Using Lemma 5, we can summarize F's contractual choice as follows.

Proposition 2. *If* $\Delta < 0$, *F implements any option contract in $\hat{A}_O$ with $p_T < -\Delta$ and obtains payoff* $\hat{\Pi}_O = \overline{N} - I$. *If* $0 \leq \Delta < \overline{N} - \tilde{\Delta} - (\overline{B} - \underline{B})$, *$F$ implements the option contract* ($i = F$, $p_C = \overline{B} - \underline{B} + \Delta$, $p_T = 0$, $o_C = N$, $o_T = N + B$) *and obtains payoff* $\tilde{\Pi}_O = \overline{N} - (\overline{B} - \underline{B}) - \Delta - I$. *If* $0 \leq \overline{N} - \tilde{\Delta} - (\overline{B} - \underline{B}) < \Delta$, *$F$ implements any renegotiation-proof contract in A^*_{NO} and obtains payoff* $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$.

Proof. For $\Delta < 0$, any contract in $\hat{A}_O$ maximizes F's payoff under the assumption of no renegotiation (Lemma 3). The subset of contracts with $p_T < -\Delta$ are renegotiation-proof (Lemma 5). Since renegotiation reduces F's payoff, F will choose a contract with $p_T < -\Delta$, resulting in payoff $\hat{\Pi}_O = \overline{N} - I$.

For $\Delta \geq \overline{N} - \max\{\underline{N}, I\}$, any contract in A^*_{NO} maximizes F's payoff (Lemma 3), and F obtains payoff $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$.

For $0 \leq \Delta < \overline{N} - \max\{\underline{N}, I\}$, $\hat{\Pi}_O > \Pi^*_{NO}$ (Lemma 3) but no option contract in $\hat{A}_O$ is renegotiation-proof (Lemma 5). We analyze whether F will implement a contract in A^*_{NO} or an option contract (F, p_C, p_T, N, $N + B$) that satisfies (1). We first compare Π^*_{NO} to the maximum payoff F can obtain from option contracts that <u>are not</u> renegotiation-proof. We then compare Π^*_{NO} to the maximum payoff from option contracts that <u>are</u> renegotiation-proof.

For both cases note that for any option contract (F, p_C, p_T, N, $N + B$) with prices p_C and p_T satisfying (1), R can find a price $\tilde{p}_C$ such that, conditional on R having chosen e_B, F accepts the renegotiation offer (F, $\tilde{p}_C$, p_T, N, $N + B$) and chooses continuation, namely any non-negative $\tilde{p}_C$

for which $\alpha \underline{N} + \varepsilon \overline{B} - p_T \leq \underline{N} - \widetilde{p}_C$, i. e. $\widetilde{p}_C \in [0, \Delta + p_T]$. Whether *R* chooses e_B and renegotiation over e_N and the original contract, depends on the original prices (p_C, p_T). *R* prefers e_B (and the contract is thus *not* renegotiation-proof) iff $\underline{B} + p_C < \overline{B} + \widetilde{p}_C$ for some $\widetilde{p}_C \in [0, \Delta + p_T]$. Substituting $\widetilde{p}_C = \Delta + p_T$, we can rewrite the condition as $p_C < \overline{B} - \underline{B} + \Delta + p_T$.

Consider now the first the case (contracts that <u>are not</u> renegotiation-proof), i. e., option contracts (F, p_C, p_T, N, $N + B$) satisfying (1) and $p_C < \overline{B} - \underline{B} + \Delta + p_T$. *F*'s payoff from implementing such a contract, after renegotiation, amounts to $\underline{N} - \widetilde{p}_C - I = \underline{N} - \Delta - p_T - I$, which is weakly smaller than $\alpha \underline{N} + \varepsilon \overline{B} - I$ and thus weakly smaller than Π^*_{NO} for any p_T in the range $0 \leq \Delta < \overline{N} - \max\{\underline{N}, I\}$. Hence, *F* will not implement this type of option contract.

Consider now the second case (contracts that <u>are</u> renegotiation-proof), i. e., option contracts satisfying $p_C \geq \overline{B} - \underline{B} + \Delta + p_T$. *F* can find prices ($p_C$, p_T) satisfying both this inequality and (1) iff $\Delta + \overline{B} - \underline{B} < \Gamma$, i. e. $\Delta < \overline{N} - (\alpha \overline{N} + \varepsilon \underline{B}) - (\overline{B} - \underline{B})$. Given any option contract satisfying these conditions, *R* will exert e_N and not renegotiate. The resulting payoff for *F*, $\overline{N} - p_C - I$ is maximized by setting $p_C = \overline{B} - \underline{B} + \Delta$ and $p_T = 0$. *F* prefers this option contract over a contract in A^*_{NO} if $\overline{N} - (\overline{B} - \underline{B}) - \Delta - I > \max\{\underline{N} - I, 0\}$, i. e. if $\Delta < \overline{N} - \max\{\underline{N}, I\} - (\overline{B} - \underline{B})$. We can thus summarize as follows: For $0 \leq \Delta < \overline{N} - \max\{\alpha \overline{N} + \varepsilon \underline{B}, \underline{N}, I\} - (\overline{B} - \underline{B})$, F chooses option contract (F, $\overline{B} - \underline{B} + \Delta$, 0, N, $N + B$) and obtains payoff $\widetilde{\Pi}_O = \overline{N} - (\overline{B} - \underline{B}) - \Delta - I$. **Q.E.D.**

Proposition 2 shows that renegotiation may reduce the range over which an option contract with termination rights and reversion of intellectual property is optimal (namely if $\Delta < \overline{N} - (\alpha \overline{N} + \varepsilon \underline{B}) - (\overline{B} - \underline{B})$). The basic finding, however, remains the same: the option contract is optimal for small Δ and thus for high α and ε. The intuition is that large outside options of the financing company correspond to a lower the value of *R*'s cooperation in the development phase. As a result, it is less costly for *F* to induce *R* to exert e_N, and the option contract becomes more profitable.

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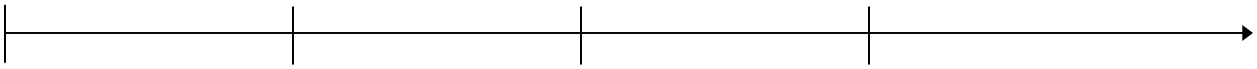
Figure 1. Timeline



t = 0
Contract

t = 1
Research
– *F* invests *I*
– *R* exerts research effort *e*

t = 2
Termination?
– Payments p_c or p_t

If continued:
Development
– *F* & *R*: preliminary manufacturing
– *F* & *R*: approval process

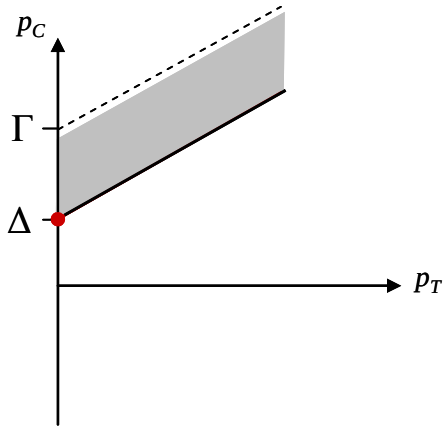
t = 3
Marketing and Sales

Figure 2. Table of Payoff

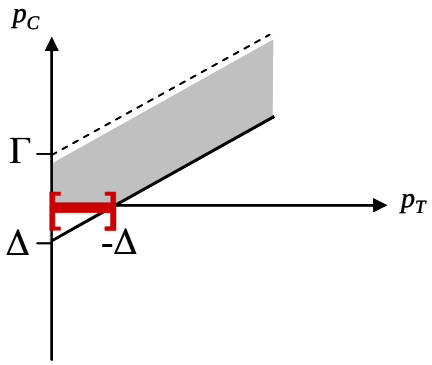
	IP Rights	*F*'s payoff	*R*'s payoff
Continuation	$o_C = \varnothing$	$-p_C$	$B + p_C$
	$o_C = N$	$N - p_C$	$B + p_C$
	$o_C = B$	$\varepsilon B - p_C$	p_C
	$o_C = N + B$	$N + \varepsilon B - p_C$	p_C
Termination	$o_T = \varnothing$	$-p_T$	$B + p_T$
	$o_T = N$	$\alpha N - p_T$	$B + p_T$
	$o_T = B$	$\varepsilon B - p_T$	p_T
	$o_T = N + B$	$\alpha N + \varepsilon B - p_T$	p_T

Figure 3. Illustration of Proposition 2

(a) $\Gamma > \Delta \geq 0$



(b) $\Gamma \geq 0 > \Delta$



(c) $0 > \Gamma > \Delta$

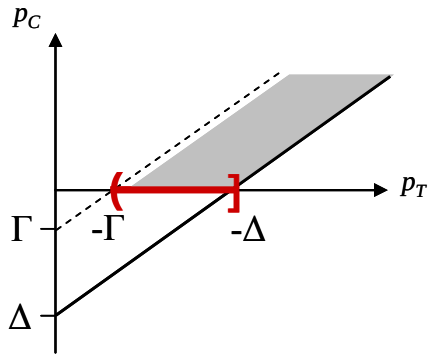


Table 1. Summary statistics. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). Date of agreement is coded as year plus one twelfth of the month in which the agreement is signed. The Carter-Manaster rank is the rating of the leading underwriter in the R&D firm's initial public offering ratings as compiled by Carter and Manaster [1990], Carter, Dark, and Singh [1998], and Ritter [2003]. The "cash burn rate" is the absolute value of the ratio of cash flow over cash and equivalents of the R&D firm.

	Mean	*Stan. Dev.*	*Min.*	*Max.*
Date of agreement	1995.3	3.7	1980	2001
Length of agreement (years)	3.9	3.2	0.9	31.0
Carter-Manaster rank of R&D firm's IPO lead underwriter	7.7	2.0	1.0	9.0
No specifiable lead product candidate at signing of research agreement	37.5%		0	1
Agreement involves diagnostic product	13.0%		0	1
Agreement involves veterinary product	5.3%		0	1
Agreement between two biotechnology firms	15.1%		0	1
Total patents of R&D firm at signing of research agreement	8.6	20.1	0	178
R&D firm's revenue in previous fiscal year ($ millions)	17.6	44.9	0	523.2
R&D firm's net income in previous fiscal year ($ millions)	-14.4	29.1	-351.9	44.3
R&D firm's cash and equivalents at end of previous year ($ millions)	46.1	134.2	0	1452.4
"Cash burn rate" of R&D firm (years)	3.2	17.6	0	295.5
Does agreement assign …				
… any termination rights?	97.7%		0	1
… any termination rights to financing firm?	96.7%		0	1
… unconditional termination rights to financing firms?	38.9%		0	1
… unconditional termination rights to financing firms that also trigger broad access to the terminated project?	11.3%		0	1

Table 2. Cross-tabulation of the financing firm's termination and broad licensing rights. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The Table presents the mean number of specified termination and broad intellectual property rights of the financing company. In Panel A, the observations are divided by whether the product was unspecifiable at the signing of the research agreement, whether the leading underwriter in the R&D firm's initial public offering is above the median Carter-Manaster style rank, whether the agreement is between two biotechnology firms, whether the R&D firm has above the median net income in the year before the signing of the research agreement, whether the R&D firm has above the median cash and equivalents at the end of the year before the research agreement, and whether the product involves a diagnostic or veterinary application. In Panel B, the observations are divided by whether the product was unspecifiable at the signing of the research agreement as well as other features of the research agreement. p-Values from t-tests of the null hypothesis that these distributions are identical are reported in the final column.

Panel A: Simple Comparisons of Termination and Broad Intellectual Property Rights

	Mean number of unconditional termination and broad intellectual property rights assigned to financing firm		
	Yes	No.	p-Value
No specifiable lead product candidate at signing of research agreement?	0.20	0.12	0.039
Carter-Manaster rank of R&D firm's IPO lead underwriter above median?	0.16	0.15	0.923
Agreement between two biotechnology firms?	0.26	0.13	0.009
R&D firm's net income in previous year above median?	0.14	0.14	1.000
R&D firm's cash and equivalents at end of previous year above median?	0.14	0.14	0.934
Does agreement involve diagnostic product?	0.05	0.16	0.047
Does agreement involve veterinary product?	0.03	0.15	0.139

Panel B: Cross-Tabulations of Termination and Broad Licensing Rights

	Mean number of unconditional termination and broad intellectual property rights assigned to financing firm		
	Yes	No.	p-Value
No specifiable lead product candidate at signing of research agreement?			
If Carter-Manaster rank of R&D firm's IPO lead underwriter above median	0.23	0.11	0.027
If Carter-Manaster rank of R&D firm's IPO lead underwriter below median	0.19	0.14	0.468
No specifiable lead product candidate at signing of research agreement?			
If agreement is between two biotechnology firms	0.44	0.11	0.006
If agreement is not between two biotechnology firms	0.14	0.12	0.590
No specifiable lead product candidate at signing of research agreement?			
If R&D firm's net income in previous year above median	0.17	0.12	0.398
If R&D firm's net income in previous year below median	0.22	0.11	0.068
No specifiable lead product candidate at signing of research agreement?			
If R&D firm's cash and equivalents at end of previous year above median	0.17	0.13	0.472
If R&D firm's cash and equivalents at end of previous year below median	0.21	0.10	0.043

Table 3. Regression analysis of the financing firm's termination and broad licensing rights. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable is the number of specified termination and broad intellectual property rights of the financing company. The independent variables in all regressions include the date of the research agreement, a dummy for agreements without specifiable lead product candidate at the signing of the research agreement, dummies for diagnostic or veterinary applications, and the Carter-Manaster style rank of the leading underwriter in the R&D firm's initial public offering. In selected regressions, the independent variables also include the count of the R&D firm's total patents at the time of the agreement, the absolute value of the ratio of cash flow over cash and equivalents of the R&D firm ("cash burn rate") at the time of the agreement, the count of previous research agreements between the two firms, and dummy variables for the year of the research agreement (not reported). The first two and last two regressions employ an ordinary least squares specification; the third and fourth, an ordered logit specification. Standard errors in brackets.

	Dep. Var.: Termination and Broad Intellectual Rights of Financing Firm					
Date of agreement	0.003	0.01	0.01	0.03		
	[0.01]	[0.01]	[0.04]	[0.04]		
No specifiable lead product candidate at signing of research agreement	0.09	0.11	0.51	0.59	0.11	0.13
	[0.04]**	[0.05]**	[0.28]*	[0.30]**	[0.04]***	[0.05]***
Agreement involves diagnostic product	-0.10	-0.09	-0.86	-0.75	-0.10	-0.09
	[0.06]*	[0.06]	[0.54]	[0.54]	[0.06]*	[0.06]
Agreement involves veterinary product	-0.12	-0.13	-1.40	-1.37	-0.13	-0.13
	[0.09]	[0.09]	[1.03]	[1.04]	[0.09]	[0.09]
Carter-Manaster rank of R&D firm's IPO lead underwriter	0.01	0.01	0.01	0.04	0.01	0.01
	[0.01]	[0.01]	[0.07]	[0.08]	[0.01]	[0.01]
Total patents of the R&D firm		0.001		0.01		0.001
		[0.001]		[0.01]		[0.001]
"Cash burn rate" of R&D firm		-0.0003		-0.004		-0.0004
		[0.001]		[0.01]		[0.001]
Number of previous research agreements between the two firms		-0.005		-0.004		-0.002
		[0.05]		[0.35]		[0.05]
Constant	-5.79	-10.29				
	[10.48]	[11.59]				
Year fixed effects	No	No	No	No	Yes	Yes
Number of observations	530	480	530	480	530	480
χ^2-statistic or F-statistic	2.44	2.03	10.23	12.15	1.09	1.06
R^2	0.02	0.02	0.02	0.03	0.05	0.06

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.

Table 4. Regression analysis of the financing firm's termination and broad intellectual property rights with pharmaceutical company fixed effects. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable is the number of specified termination and broad intellectual property rights of the financing company. The independent variables in all regressions include the date of the research agreement, a dummy for agreements without specifiable lead product candidates at the signing of the research agreement, dummies for diagnostic or veterinary applications, the Carter-Manaster style rank of the leading underwriter in the R&D firm's initial public offering and dummy variables for the financing companies (not reported). In selected regressions, the independent variables also include the count of the R&D firm's total patents at the time of the agreement, the absolute value of the ratio of cash flow over cash and equivalents of the R&D firm ("cash burn rate") at the time of the agreement, the count of previous research agreements between the two firms, and dummy variables for the year of the research agreement (not reported). All regressions employ an ordinary least squares specification. Standard errors in brackets.

	Dependent Variable: Termination and Broad Intellectual Property Rights of Financing Firm			
Date of agreement	0.002	0.005		
	[0.01]	[0.01]		
No specifiable lead product candidate at signing of research agreement	0.09	0.10	0.11	0.13
	[0.04]**	[0.05]**	[0.04]**	[0.05]***
Agreement involve diagnostic product	-0.10	-0.09	-0.10	-0.08
	[0.06]*	[0.06]	[0.06]	[0.07]
Agreement involve veterinary product	-0.11	-0.11	-0.12	-0.11
	[0.09]	[0.09]	[0.09]	[0.10]
Carter-Manaster rank of R&D firm's IPO lead underwriter lead	0.01	0.01	0.005	0.01
	[0.01]	[0.01]	[0.01]	[0.01]
Total patents of the R&D firm		0.001		0.001
		[0.001]		[0.001]
"Cash burn rate" of R&D firm		-0.0003		-0.0003
		[0.001]		[0.001]
Number of previous research agreements between the two firms		-0.02		-0.02
		[0.05]		[0.05]
Financing company fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	No	No	Yes	Yes
Number of observations	530	480	530	480
F-statistic	1.30	1.28	1.04	1.03
R^2	0.04	0.06	0.07	0.09

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.

Table 5. Regression analysis of the financing firm's termination and broad intellectual property rights, divided by proxies for R&D firm's financial constraints. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable is the number of specified termination and broad intellectual property rights of the financing company. The independent variables in all regressions include the date of the research agreement, a dummy for agreements without specifiable lead product candidate at the signing of the research agreement, dummies for diagnostic or veterinary applications, the Carter-Manaster [1990] style rank of the leading underwriter in the R&D firm's initial public offering, the count of the R&D firm's total patents at the time of the agreement, the absolute value of the ratio of cash flow over cash and equivalents of the R&D firm ("cash burn rate") at the time of the agreement, and the count of previous research agreements between the two firms. In the first pair of regressions, observations are divided by whether the R&D firm has above or below the median net income (-$7.7 million); in the third and fourth, whether the R&D firm has above or below the median cash and equivalents ($12.7 million). All employ an ordinary least squares specification. Standard errors in brackets.

	Dependent Variable: Termination and Broad Intellectual Property Rights of Financing Firm			
	Measured on Net Income		Measured on Cash and Equivalents	
	Below Median	**Above Median**	**Below Median**	**Above Median**
Date of agreement	0.004	0.01	0.01	-0.003
	[0.01]	[0.01]	[0.01]	[0.01]
No specifiable lead product candidate at signing of research agreement	0.15	0.07	0.14	0.07
	[0.07]**	[0.06]	[0.07]**	[0.06]
Agreement involve diagnostic product	-0.07	-0.07	-0.15	-0.004
	[0.09]	[0.09]	[0.09]*	[0.08]
Agreement involve veterinary product	-0.10	-0.13	-0.12	-0.09
	[0.13]	[0.13]	[0.12]	[0.13]
Carter-Manaster rank of R&D firm's IPO lead underwriter	0.02	0.01	0.01	0.01
	[0.01]	[0.02]	[0.02]	[0.01]
Total patents of the R&D firm	0.002	0.004	-0.004	0.002
	[0.001]	[0.004]	[0.006]	[0.001]
"Cash burn rate" of R&D firm	-0.0002	-0.0003	-0.001	-0.09
	[0.002]	[0.002]	[0.001]	[0.06]
Number of previous research agreements between the two firms	-0.03	0.02	0.03	-0.01
	[0.07]	[0.09]	[0.11]	[0.06]
Constant	-8.47	-20.21	-28.57	6.48
	[22.19]	[14.85]	[16.20]*	[18.23]
Number of observations	247	233	235	245
F-statistic	1.36	1.09	2.08	1.14
R^2	0.04	0.04	0.07	0.04

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.

Table 6. Regression analysis of the financing firm's termination and broad intellectual property rights, divided by proxies for the type of financing firm. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable is the number of specified termination and broad intellectual property rights of the financing company. The independent variables in all regressions include the date of the research agreement, a dummy for agreements without specifiable lead product candidate at the signing of the research agreement, dummies for diagnostic or veterinary applications, and the Carter-Manaster [1990] style rank of the leading underwriter in the R&D firm's initial public offering (in the first pair of regressions only). Observations are divided by whether by whether the research agreement is between two biotechnology firms. All employ an ordinary least squares specification. Standard errors in brackets.

	Dependent Variable: Termination and Broad IntellectualProperty Rights of Financing Firm Divided by Whether Agreement is Between Two Biotechnology Firms	
	Yes	**No**
Date of agreement	-0.03	0.01
	[0.02]	[0.01]
No specifiable lead product candidate at signing of research agreement	0.29	0.05
	[0.13]**	[0.04]
Agreement involve diagnostic product	-0.27	-0.07
	[0.23]	[0.06]
Agreement involve veterinary product	-0.23	-0.09
	[0.29]	[0.09]
Carter-Manaster rank of R&D firm's IPO lead underwriter	0.03	0.001
	[0.03]	[0.01]
Constant	56.46	-9.91
	[47.71]	[10.43]
Number of observations	77	453
F-statistic	2.05	1.15
R^2	0.13	0.01

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.

Table 7. Regression analysis of the financing firm's termination and broad intellectual property rights, with interaction terms for firm profitability and the type of financing firm. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable is the number of specified termination and broad intellectual property rights of the financing company. The independent variables in all regressions include the date of the research agreement, a dummy for agreements with diagnostic or veterinary applications, the Carter-Manaster [1990] style rank of the leading underwriter in the R&D firm's initial public offering, the count of the R&D firm's total patents at the time of the agreement, the absolute value of the ratio of cash flow over cash and equivalents of the R&D firm ("cash burn rate") at the time of the agreement, and the count of previous research agreements between the two firms. The first regression also includes dummies for whether the firm is above or below the median net income in the fiscal year prior to the research agreement, and interactions between these dummies and a dummy for agreements without specifiable lead product candidate at the time of the research agreement. The second regression also includes dummies for whether the financing company is a biotechnology firm or a pharmaceutical company, and interactions between these dummies and a dummy for agreements without specifiable lead product candidate at the time of the research agreement. All employ an ordinary least squares specification. Standard errors in brackets.

	Dependent Variable: Termination and Broad Intellectual Property Rights of Financing Firm	
	Net-Income Interaction	**Type-of-Financing-Firm Interaction**
Date of agreement	0.01	0.004
	[0.01]	[0.006]
Agreement involves diagnostic product	-0.08	-0.09
	[0.08]	[0.06]
Agreement involves veterinary product	-0.16	-0.11
	[0.11]	[0.09]
Carter-Manaster rank of R&D firm's IPO lead underwriter	0.01	0.01
	[0.01]	[0.01]
Total patents of the R&D firm	0.003	0.001
	[0.001]*	[0.001]
"Cash burn rate" of R&D firm	-0.001	-0.001
	[0.001]	[0.06]
Number of previous research agreements between the two firms	-0.01	0.0003
	[0.06]	[0.05]
Above median net income	-18.97	
	[15.51]	
Below median net income	-19.10	
	[15.54]	
Agreement between two biotechnology firms		-8.91
		[11.61]
Agreement between a biotechnology and a pharmaceutical firm		-8.90
		[11.60]
Above median net income and no specified lead product at signing	0.08	
	[0.08]	
Below median net income and no specified lead product at signing	0.20	
	[0.08]**	
Biotech-biotech agreement and no specified lead product at signing		0.31
		[0.11]***
Biotech-Pharma agreement and no specified lead product at signing		0.07
		[0.05]
Number of observations	480	480
F-statistic	6.88	7.21
R^2	0.14	0.14

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.

Table 8. Regression analysis of the financing firm's termination and broad intellectual property rights, divided by proxies for the R&D company quality. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable is the number of specified termination and broad intellectual property rights of the financing company. The independent variables in all regressions include the date of the research agreement, a dummy for agreements without specifiable lead product candidate at the signing of the research agreement, dummies for diagnostic or veterinary applications, and the Carter-Manaster [1990] style rank of the leading underwriter in the R&D firm's initial public offering (in the first pair of regressions only). Observations are divided by whether by whether the R&D firm has above or below the median Carter-Manaster rank of the lead underwriter (8.75). All employ an ordinary least squares specification. Standard errors in brackets.

	Dep. Var.: Termination and Broad Intellectual Property Rights of Financing Firm Divided by Underwriter Reputation	
	Above Median	**Below Median**
Date of agreement	0.005	0.001
	[0.01]	[0.01]
No specifiable lead product candidate at signing of research agreement	0.13	0.04
	[0.06]**	[0.07]
Agreement involve diagnostic product	-0.14	-0.04
	[0.08]*	[0.09]
Agreement involve veterinary product	-0.12	-0.08
	[0.11]	[0.15]
Carter-Manaster rank of R&D firm's IPO lead underwriter	-0.0004	0.01
	[0.27]	[0.01]
Constant	-8.88	-2.03
	[14.84]	[14.61]
Number of observations	307	223
F-statistic	2.87	0.44
R^2	0.04	0.01

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.

Table 9. Regression analyses using alternative dependent variables. The sample consists of 584 research agreements entered into between biotechnology firms ("R&D firms") and pharmaceutical or larger biotechnology companies ("financing companies"). The dependent variable in the first four regressions is the number of specified termination rights of the financing company. The dependent variable in the fifth and sixth regressions is the number of specified provisions assigning termination and broad intellectual property rights to the financing company only in well-defined circumstances ("conditional termination and licensing rights"). The independent variables in all regressions include the date of the research agreement, a dummy for agreements without specifiable lead product candidate at the signing of the research agreement, dummies for diagnostic or veterinary applications, and the Carter-Manaster style rank of the leading underwriter in the R&D firm's initial public offering. In selected regressions, the independent variables also include the count of the R&D firm's total patents at the time of the agreement, the absolute value of the ratio of cash flow over cash and equivalents of the R&D firm ("cash burn rate") at the time of the agreement, and the count of previous research agreements between the two firms. The first two regressions employ an ordinary least squares specification; the third and fourth, an ordered logit specification. Standard errors in brackets.

	Dependent Variable:					
	Termination Rights of Financing Firm				*Conditional Termination and Broad Property Rights*	
Date of agreement	-0.004	-0.01	-0.03	-0.03	0.003	0.005
	[0.01]	[0.01]	[0.02]	[0.02]	[0.003]	[0.003]
No specifiable lead product candidate at signing of research agreement	-0.11	-0.09	-0.29	-0.22	0.03	0.02
	[0.07]	[0.08]	[0.19]	[0.20]	[0.03]	[0.03]
Agreement involve diagnostic product	-0.28	-0.28	-0.87	-0.86	-0.04	-0.04
	[0.10]***	[0.10]***	[0.29]***	[0.30]***	[0.03]	[0.04]
Agreement involve veterinary product	-0.16	-0.17	-0.47	-0.45	0.06	0.01
	[0.15]	[0.15]	[0.41]	[0.42]	[0.05]	[0.01]
Carter-Manaster rank of R&D firm's IPO lead underwriter	0.02	-0.01	0.001	0.005	0.01	0.01
	[0.02]	[0.02]	[0.05]	[0.05]	[0.01]	[0.01]
Total patents of the R&D firm		-0.0001		-0.002		-0.001
		[0.002]		[0.01]		[0.001]
"Cash burn rate" of R&D firm		-0.001		-0.002		0.0003
		[0.002]		[0.005]		[0.0006]
Number of previous research agreements between the two firms		0.01		0.08		0.03
		[0.09]		[0.21]		[0.03]
Constant	8.39	10.91			-6.90	-9.32
	[17.92]	[19.77]			[6.01]	[6.74]
Number of observations	530	480	530	480	530	480
χ^2-statistic or F-statistic	2.96	1.53	15.76	13.70	1.57	0.96
R^2	0.03	0.03	0.02	0.01	0.01	0.02

* = significant at the 10% confidence level; ** = significant at 5% level; *** = significant at the 1% level.