Contractibility and the Design of Research Agreements*

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Abstract

We analyze how contractibility affects the design of contracts. Our empirical application is biotechnology research. A major concern in biotechnology research agreements is that the researchers might use their funding to subsidize other projects. We develop a model that allows for researchers to pursue multiple projects. When research activities are contractible, a complete contract achieves the first best. When research activities are not contractible, instead, an option contract is optimal. The financing firm obtains the right to terminate the research agreement and, in case of termination, broad property rights. The threat of termination induces the researchers to adhere to the proposed research agenda, while the cost of exercising the option deters the financing firm from opportunistically terminating the agreement. We test this prediction using a new data set of 580 biotechnology research agreements. We find that the option contract is more common when research is non-contractible. We also analyze how the contractual design varies with the research firm's financial constraints and quality. The additional empirical results allow us to distinguish the property-rights explanation from explanations 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 areas in economics, ranging from labor economics and corporate finance to modern macroeconomics. An important distinction, introduced by the literature on incomplete contracts, is the observability and verifiability of actions and outputs (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 reallocating asset ownership.

We analyze how the design of contracts varies as underlying variables become harder or easier to verify. We study, 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.

Our empirical application is biotechnology research. Innovation in the biotechnology sector is frequently based on research agreements between a financing firm (typically a large pharmaceutical company) and a research firm (typically a smaller biotechnology company). A key difficulty for such collaborations is that the two parties have different goals. The objective of the financing firm is a viable and profitable drug. The objective of the researchers, instead, is to advance a portfolio of different research projects and to achieve academic targets, which do not necessarily coincide with the drug approval. A common concern of financing firms entering research agreements, therefore, is that the biotechnology researchers use their funds for other types of research, which has been termed "project substitution" or "project cross-subsidization."

We explore theoretically and empirically how the contractual response to this incentive conflict depends on the contractibility of research. We first provide a simple model based on the property-rights theory of the firm, in particular Hart and Moore (1988) and Nöldeke and Schmidt (1995), which allows for multi-tasking in the sense of Holmström and Milgrom (1991). If research effort is observable and verifiable, the incentive problem can be solved with a simple complete contract. This is the case when the biotechnology researchers have to perform a series of specifiable experiments on a lead product candidate. Often, however, research is not contractible. We show that, in this case, option contracts are second-best optimal. The option contract gives the financing company the right to terminate the collaboration while obtaining broad property rights in case of termination. The reversion of broad property rights from the research to the financing firm in case of termination generates the right incentives for the research firm at the lowest cost to the financier. The optimal contract also determines payments upon termination so that the financing firm does not exercise the termination option opportunistically.

However, the optimal option contract allows the financing firm to extract less profit than in a complete-contracts world, in which it can contract directly on research activities. Therefore, whenever research is contractible, the financing firm prefers to offer a complete contract. Thus,

the model predicts the use of option contracts with termination clause and property-rights reversion in contractually difficult environments, but not otherwise.

The model also implies that this prediction does not need to hold if the research firm is financially unconstrained. If the research firm is liquid, option contracts allow the financing firm to extract the first-best payoff both when research is contractible and when it is not contractible. Moreover, when research is not contractible, various types of option contracts achieve the same first-best payoff.

We test the predictions of our model in a novel data set of 580 research agreements in the biotechnology sector. We first provide evidence of the underlying project cross-subsidization problem. We show that multi-tasking is commonplace for research firms in our sample, as measured by the number of simultaneous research alliances. We then test whether research agreements are indeed more likely to employ termination clauses, coupled with expanded access to the intellectual property, when research is non-contractible. Using the lack of a specifiable lead product candidate as a proxy for non-contractible research, we find the empirical prediction confirmed in the data. Moreover, the positive correlation of option contracts and non-contractibility holds (and is stronger) in the subset of the most financially constrained firms. It is insignificant for liquid research firms, though the differences in coefficients are not statistically significant.

We employ several additional tests and alternative proxies to distinguish the incomplete-contracts interpretation from other explanations of the observed contract design. One concern is that, in collaborations without a specifiable lead compound, the financing firm might be providing inputs into research beyond mere financing, and that the contract design may reflect this dual role. We address this concern with a detailed analysis of the contractual language and the delineation of the financing firm's role in those agreements. We also retrieve all patents awarded to the financing firm to measure its expertise in the field of the alliance. Using either approach, excluding financing firms who might provide non-financial input does not weaken (and typically strengthens) the results. Other concerns and alternative explanations, such as heterogeneity in uncertainty, in informational asymmetry, or in the "abilities" of the research firm, would predict a correlation with specific termination clauses and not with broad intellectual property rights. The data rejects the predicted alternative correlations. Finally, proxies for the research quality of the research firm address the alternative 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 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 ac-

cess to property rights may remedy contracting difficulties. Our explanation is based on the assumption of contractual incompleteness, which appears to be plausible in research agreements.

Much of the prior literature analyzing "real-world contract design" has focused on complete rather than incomplete contracts.[1] This may reflect empirical difficulties in pinning down theoretical concepts such as observability, verifiability and incompleteness. Two leading exceptions are the work by Kaplan and Stromberg (2003 and 2004) and by Baker and Hubbard (2003 and 2004). 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 exploits a switch in the monitoring technology of truck drivers, which allows for contracts previously not feasible. The subsequent evolution of contracts confirms the role of asset ownership to deal with limits to contracting. Our approach more closely resembles the latter. We identify an empirical proxy for contractibility and relate variations in contractibility to variations in contract design. Similar to previous work on strategic alliances (Robinson and Stuart (2007)), we focus on specific contractual clauses (namely option rights to terminate). Our large, hand-collected data set on research agreements allows us to address several concerns plaguing that literature, such as unobserved firm characteristics (via firm fixed-effects and firm-level controls), and to test directly competing explanations.

Prior empirical tests of the property-rights theory of the firm (e.g. Monteverde and Teece (1982); Acemoglu, Aghion, Griffith, and Zilbotti (2004)) have largely focused on the "make or buy" decisions.[2] The theoretical literature, however, pioneered by Grossman and Hart (1986) and Hart and Moore (1988, 1990), goes beyond the question of integration versus outsourcing. In theory, the contracting parties may design *any* suitable decision right to govern non-contractible actions. Our paper attempts to help fill this gap by focusing on the role of termination rights.[3] Compared to previous work on strategic alliance and venture capital contracts (Cornelli and Yosha (2003), Dessein (2005), Schmidt (2003), and Nöldeke and Schmidt (1998)), which focuses on the transfer of control rights over a company or joint venture, we de-emphasize the role of firm ownership. The financing firm may not have much interest in acquiring the research firm and may lack the research expertise required to benefit from residual control rights.[4]

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[1] Chiappori and Salanie (2003) survey research testing the implications of asymmetric information and moral hazard.

[2] Our paper is similar in spirit to Azoulay (2004), who also examines how information problems affect contracting in the biomedical industry, and to Guedj (2006), who also analyzes opportunistic *ex post* behavior after an agreement is signed. Unlike Guedj, we also ask how contract design can anticipate and shape such behavior.

[3] 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.

[4] Other papers have addressed the selection of projects for biotechnology alliances. Pisano (1997) posits a "lemons" problem, whereby biotechnology companies license their less promising drugs while retaining the promising ones to develop by themselves. Danzon, Nicholson, and Pereira (2005) find no support for this hypothesis in an examination of 900 alliances. Our analysis differs from these in that it focuses not on the *ex ante* selection of projects for alliances, but rather on the *ex post* behavior after the contract is signed.

Our theoretical framework relates to the literature on financial contracting, in particular Aghion and Bolton (1992). Like Aghion and Bolton, we consider the decision of a firm to provide capital to another company in return for some decision rights. Similar to Aghion and Tirole (1994), our model emphasizes inefficiencies due to financial constraints. As in their work, financial constraints of the research unit prevent the first-best outcome if research efforts are non-contractible, and the allocation of product ownership helps to alleviate this problem.

Finally, the incentive conflict of "academic" versus "commercial" research has been analyzed outside of contract theory (e.g., Cockburn, Henderson, and Stern (1999)).

The remainder of the paper is organized as follows. In Section II, we present stylized facts on research collaborations in the biotechnology sector, incentive conflicts between the contracting partners, and the empirical contract design. Section III presents a model that reconciles the empirical contract design with the observed incentive conflicts. We test the predictions of the model on a novel contracts data set, introduced in Section IV. The empirical tests of our predictions and alternative hypotheses are in Section V. Section VI concludes the paper.

II. Incentive Conflicts in Biotechnology Research Collaborations

Innovative activities in the biotechnology sector increasingly take place as research collaborations. While the initial biotechnology firms relied primarily on capital raised on public markets, research alliances surpassed public offerings in the 1990s as the dominant source of financing.[5] These research collaborations consist of three phases: research, development, and marketing and sales. Typically, a pharmaceutical company provides the initial financing and a biotechnology company provides the bulk of the research. The development of the drug is undertaken jointly. Marketing and sales are mostly in the hands of the financing company. As the dominant research-performing entity, the biotechnology firm receives the intellectual property rights, but commits to license the relevant patent holdings and know-how to its partner. The right to manufacture the product may be assigned to one of the parties or divided between the two. Most of the profits from the final project go to the financing company, though the research company also reaps a certain percentage via the royalties from licensing.

The pervasiveness of research agreements in the biotechnology sector is puzzling since the interests of the two partners are typically not 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 financing firms entering into research agreements. While it is the objective

[5] See Lerner and Merges (1998).

of the financing firm to develop a certain viable and profitable drug, the research firm has multiple interests. On the one hand, the researchers 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 projects may be in collaboration with other pharmaceutical or biotechnology firms. Others may be the development of wholly owned products, from which the research firm receives all the profits. Success in solely developed products is particularly valued by equity markets as an indicator of the acumen of the research firm's management. As a result, researchers are tempted to employ resources from a specific research agreement on other projects.[6]

In another interview, a lawyer frequently involved in the negotiation of these agreements also highlighted cross-subsidization as a major concern. He argued that, while formal dispute-resolution mechanisms partially address these problems, some disputes cannot be resolved in negotiations, and financing firms insist on the right to unilaterally back out of the agreements. He indicated that these terms are far more likely in a negotiation involving an early-stage technology.

In addition to these commercial conflicts, researchers in biotechnology companies are often more academically oriented than the financing firms.[7] Many biotechnology firms are founded and guided by long-time academics who still want to impact the academic discussion. They often employ post-doctoral students who are considering an academic career. Furthermore, 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 biotechnology company may want to spend extra time and money running additional experiments to satisfy academic requirements for a publication in a top journal, when there is already sufficient evidence to start the approval process at the U.S. Food and Drug Administration. These pressures may lead to biotechnology firms pursuing research that is more fundamental than the financing firm would prefer and to seeking publication before the financing company prefers the findings to become known.

A variant of this incentive problem is that researchers tend to terminate unsuccessful projects too late. This can happen for several reasons. First, additional research on a project might be beneficial to the researcher's scientific reputation even though it is not profit maximizing for the financing firm. Second, it appears to be hard for researchers to admit that a project ought to be terminated.[8] Researchers and especially founders of biotechnology firms may be "attached" to the initial biotechnological component since it constitutes their principal discovery. Such behavior has been labeled "founder syndrome." In fact, we learned in the course of our interviews that

[6] For instance, in 1993, established biotechnology firm Alkermes sued its smaller contracting partner, Cortex Pharmaceuticals. 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).

[7] Stern (2004) points out that scientists are willing to accept lower wages in return for more science-oriented research.

[8] Cf. Stulz (1990).

founders often leave the company when the initial technology is abandoned, asserting that they do not "morally own" the company any more. Third, the researchers in the biotechnology firm may have empire-building preferences and attempt to maximize the number of ongoing projects.

These types of moral hazard problems can be interpreted as a form of project cross-subsidization. Similar to working on a different project than agreed upon, researchers may continue working on a project even though the financing firm would like them to declare the research to be either completed or unsuccessful. In either case, it is often hard for financing firms to determine when the biotechnology researchers are engaging in such undesired research.

An illustration of the concerns about opportunistic behavior of the research firm is the research agreement between ALZA, a California-based drug delivery company founded in 1968, and the Swiss pharmaceutical giant Ciba-Geigy.[9] The two firms signed a research agreement in 1978. ALZA also engaged in a variety of independent activities, including 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. Despite these seemingly ironclad control rights, 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 collaborations that ALZA representatives kept seeking to establish with third parties. 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 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 were also concerend that ALZA scientists were publishing material in journals that disclosed their proprietary technology or might be employed in ALZA's collaborations with other pharmaceutical firms. As a result, Ciba-Geigy 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 importance of the types of problems delineated above on research collaborations.

In a subset of cases, the parties can remedy this incentive conflict directly by specifying the exact research activities to be undertaken by the researchers. In these cases, the parties have typically identified a specific lead product candidate at the beginning of their collaboration. It is

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

thus relatively easy for them to separate out unrelated research. In many cases, however, the exact lead product candidate is not yet specifiable and the research agreement is entered without a clear 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. In these cases, it is difficult to delineate the boundaries of a project. In this paper, we specifically exploit 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 research agreements. The model also illustrates the role of financial constraints and their interaction with contractibility.

We first present the basic framework (and motivate the assumptions), then discuss the roadmap we follow, and finally present the results in three different scenarios.

Basic framework. We consider a research firm R and a financing firm F, both risk-neutral. (All variable definitions are listed in Appendix A.) The model has four phases, as depicted in Figure 1: contracting at $t = 0$, research ($t = 1$), development ($t = 2$), and marketing and sales ($t = 3$). We initially assume that R is credit constrained. Hence, there is no possibility of monetary transfers from R to F. If F provides financing I then R can perform research. R's research yields an intermediate product at $t = 2$. If advanced through development, marketing, and sales, this technology generates two types of non-negative and non-contractible surplus: "narrow" (or "commercial") surplus N from the sales of the envisioned product of the research collaboration, and "broad" (or "scientific") surplus B, which represents profits and scientific reputation from unrelated discoveries. For simplicity, we assume that both types of surplus are deterministic.[10]

The basic conflict arises from R's interest in broad (scientific) surplus B. Specifically, we assume that, in the research phase ($t = 1$), R can either focus on the narrow project specified in the research agreement or engage in broader research. Narrow research effort e_N generates high narrow surplus, $\overline{N}$, but low broad surplus, $\underline{B}$, while broad research effort e_B results in low $\underline{N}$ and high $\overline{B}$. We assume $\overline{N} > I$. Both types of surplus are realized after commercialization at $t = 3$.

The amount of surplus extracted in $t = 3$ depends on (i) whether the parties continue to collaborate at $t = 2$ and (ii) the allocation of property rights. As for (i), the full amount of narrow surplus N is generated only if the parties continue to collaborate. If they terminate the collaboration after $t = 1$, they generate strictly less than the full N. The ex-post efficiency loss from termination reflects the specialization of biotechnology researchers and the search costs to find a new

[10] The results are unchanged if we assume that surplus is stochastic and its expected value only depends on R's effort.

partner. Broad surplus B, however, does not depend on continued collaboration as it captures the value of future projects with different partners and general scientific reputation.

As for (ii), since surplus is non-contractible, it accrues to the holder of the intellectual property rights. Rights to narrow and to broad surplus can be contracted on separately. Narrow rights (typically licensing rights) allow the holder to sell the envisioned product of the collaboration, i.e. to reap N. Broad rights allow the holder to develop and sell side products and to claim the intellectual ownership, i.e., to reap B. We assume that these rights are of different value for F and for R. If F obtains the narrow rights, it can extract all the available narrow surplus. If R obtains the narrow rights, it cannot extract any portion of N. This assumption captures the fact that success in the final marketing and sales stages depends on the capacity of F to undertake large-scale manufacturing as well as on F's marketing and distribution channels. On the other hand, R can extract the full broad surplus B if it has the broad rights while F can extract only strictly less B if granted the broad rights. This assumption captures the different nature of B. Future research, building on the broad technology, enhances scientific reputation and is more valuable to the academically oriented researchers than to the financing firm. We also assume that

R chooses e_B if indifferent between e_N and e_B. **(A.1)**

A.1 can be interpreted as a reduced-form substitute for modeling non-transferable benefits for R from the broader research, such as acquiring non-transferable general human capital. The higher value of broad surplus for R generates R's incentive to "cross-subsidize," i.e., to invest in broader, more scientific research rather than the envisioned marketable product.

We assume that F makes a take-it-or-leave-it offer to R and that there is no renegotiation.[11] The assumption of a take-it-or-leave-it offer reflects that there are many research firms 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 if and only if its payoff is at least the value of the broad rights after narrow effort, $\underline{B}$:

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

We consider three contractual scenarios. First, we derive the optimal contract under the assumption that e is contractible. Next, we derive the optimal no-option contract under the assumption that R's research is observable[12] at $t = 2$ but is not verifiable. Finally, we introduce option rights and ask whether they allow the financing firm to extract a higher payoff. In particular, we consider the option to terminate the research collaboration after $t = 1$, i.e., after F has observed

[11] There is scope for renegotiation after R has exerted the research effort e. We consider renegotiation in Appendix C.

[12] We also developed an alternative model where F cannot observe e directly but infers it from the stochastic 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.

e and thus the (future) surplus resulting from *e*. This implies that the courts can observe termination, i.e., which party (if any) decided not to continue the collaboration. We assume

F terminates if indifferent between termination and continuation. **(A.3)**

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

In our framework, a contract specifies:

(i) the initial payment I of the financing firm at $t = 1$,

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

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

(iv) the narrow and broad property rights of *F* and *R*.

In the benchmark scenario of contractible effort *e*, the parties can condition (ii)–(iv) on *e*. If *e* is observable but not verifiable, (ii)–(iv) cannot be conditioned on *e*. If option contracts are used, it is verifiable whether the option-holder exercises the option right to terminate, and (ii)-(iv) can thus be conditioned on continuation or termination. Formally, the payment $p \geq 0$ from *F* to *R* can be conditioned on *e* in the case of contractible *e* and only on continuation *C* or termination *T* (denoted as $p_C \geq 0$ and $p_T \geq 0$) otherwise. We denote the property rights assigned to *F* with *o* and, in case of an option contract, as o_C and o_T in case of continuation and termination respectively. With some abuse of notation, we denote that

- *F* receives no intellectual property rights after action *a* as $o_a = ø$,
- *F* receives broad rights as $o_a = B$,
- *F* receives narrow rights as $o_a = N$, and
- *F* receives both broad and narrow rights as $o_a = B + N$.

Roadmap. We explore this incentive conflict under the different contractibility assumptions (*e* contractible, non-contractible without option contracts, non-contractible with option contracts) in three set-ups.

1. We start from a simple set-up in which *F* does not benefit at all from broad research or from continuing the collaboration with other researchers. That is, we assume that *F* extracts zero payoff from *B* even when it has the rights to *B* (and regardless of whether the parties continue to collaborate), and that it extracts zero payoff from *N* after termination even if it has the rights to *N*. Even under these stark assumptions, we show that the type of option contract that we observe

[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, *F* cannot simply "seize" 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.

empirically (namely, a contract assigning F the right to terminate and, in case of termination, the rights to B) increases F's payoff relative to contracting without option rights.

2. We then extend the set-up and introduce some 'outside benefits' for F. That is, we assume that F can extract a portion ε, $\varepsilon \in (0,1)$, of the broad surplus B (if assigned the broad property rights) and a portion α, $\alpha \in (0,1)$, of the narrow surplus N even after termination (if assigned the narrow property rights). Under these more realistic assumptions, termination is less costly for F and the threat of termination is larger. As a result, the option contract strictly dominates other contracts, and we derive the empirical prediction that the use of such option contracts is correlated with contractually difficult environments.

3. In the last step, we remove the assumption of financial constraints. We show that, if R is liquid, then F can always obtain the same surplus as in a world with contractible effort, either with or without employing an option contract. Thus, we do not have a clear prediction about the use of option contracts in contractually difficult environments when research firms are liquid.

III.1. Simple set-up: F has no outside options

We start from the simplified setting in which F cannot extract any portion of B and cannot extract any portion of N after termination. Hence, F's payoff in case of continuation is either $N - p_C - I$ or $-p_C - I$, depending on whether F has the narrow rights. F's payoff in case of termination is always $-p_T - I$. (Figure 2.a summarizes the payoffs.) Thus, F's payoff is weakly higher under $e = e_N$ than under $e = e_B$ for each contract scenario. Moreover, F can obtain a positive payoff only under continuation and for $o_C = B + N$ or $o_C = N$.

Contractibility. If e is contractible, F can obtain the maximum attainable payoff $\overline{N} - I$ by contracting on e_N, reserving the rights to N for itself, allocating B to R, and setting $p = 0$.

To see that $\overline{N} - I$ is the maximum attainable payoff, note that the minimum payment from F to R satisfying R's participation constraint is $p = \underline{B}$ if R does not obtain the rights to B (i.e., for $o = B + N$ or $o = B$) and $p = 0$ if R obtains at least the broad rights (i.e., for $o = N$ or $o = \varnothing$). Employing the minimum price and maximizing F's payoff over e and across the different contract scenarios, we find that F's payoff is maximized under $e = e_N$, and $o = N$, resulting in a net payoff of $\overline{N} - I$ for F and of $\underline{B}$ for R.

Note that this is not the surplus-maximizing outcome if $\overline{B} + \underline{N}$ is larger than $\underline{B} + \overline{N}$. In this case, the financial constraints of the research firm (combined with our restriction of the contract space to non-stochastic contracts) prevent the parties from achieving the first-best outcome and having the research firm compensate its partner *ex ante*, akin to Aghion and Tirole (1994).

Limited contractibility without options. If e is observable but not verifiable, the parties cannot condition payments and actions on e. Thus, in contracts without option rights, R will always choose e_B. As in the case of contractible e, 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 payoff is $\underline{N} - I$, and R gets $\overline{B}$ if a contract is signed. However, if $\underline{N} < I$, F does not make any offer and the parties forgo the narrow and broad surplus. We denote the set of contracts that maximize F's profit in the class of contracts without options (including "no contract") as A^*_{NO} and the resulting payoff for F as Π^*_{NO}, with $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$. If a contract is signed, R extracts a rent of $\overline{B} - \underline{B}$ beyond the reservation utility.

Limited contractibility with options. We now ask whether a broader class of contracts allows F to reap a higher payoff. In particular, we consider the role of termination rights. We denote as $A_O = (i, p_C, p_T, o_C, o_T)$ contracts that assign the option right to terminate to $i \in \{R, F\}$. 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 payoff for F than the second-best no-option contract A^*_{NO}.

Proposition 1. *If research effort is not contractible but the increase in narrow surplus from exerting e_N rather than e_B is large, namely $\overline{N} - \underline{N} > \max\{\underline{N}, I\}$, then F reaps a higher payoff (than the maximum payoff without option rights) from an option contract that assigns F the right to terminate after t = 1 and, only in case of termination, the broad property rights.*

To prove Proposition 1, we prove three Lemmas, which jointly imply Proposition 1.

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

$$\overline{N} > p_C - p_T \geq \underline{N}. \tag{1}$$

Proof of Lemma 1. To induce e_N, F needs to terminate after e_B and to continue after e_N ; else R would always choose the preferred effort e_B (assumption A.1) and obtain a weakly higher payoff. Under the contractual provisions $i = F$, $o_C = N$, and $o_T = N + B$, F terminates after e_B iff $\underline{N} - p_C \leq -p_T$ and continues after e_N iff $\overline{N} - p_C > -p_T$. Solving these two inequalities for $p_C - p_T$ yields (1). Given F's conditional termination decisions, R receives payoff p_T after e_B and $\underline{B} + p_C$ after e_N. Hence, R chooses e_N if and only if $p_C - p_T > -\underline{B}$. This is implied by (1). Hence, prices (p_C, p_T) satisfying (1) are necessary and sufficient to induce F to terminate iff R chooses e_B. **Q.E.D.**

To provide some intuition for double-inequality (1), note that the upper bound of the price differential between continuation and termination, $\overline{N}$, ensures that F chooses continuation after e_N. Similarly, the lower bound $\underline{N}$ ensures that F chooses termination after e_B. In addition, an option contract satisfying (1) relies on two main features. First, termination drastically reduces the amount of narrow surplus F can obtain. Thus, holding other payoffs constant, F prefers continuation over termination. Second, R is deprived of the broad surplus in case of termination. The reversal of broad rights makes the threat of termination less costly to F.

We can now characterize, within the above class of incentive-compatible option contracts, the payoff-maximizing contract.

Lemma 2. *In the set of option contracts* $(F, p_C, p_T, N, N+B)$ *that implement* e_N, *setting* $p_C = \underline{N}$ and $p_T = 0$ *maximizes F's payoff.*

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

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

where the second constraint is the participation constraint for R, and the constraints in the last line capture R's financial constraints. We can simplify the objective function to $\min_{p_C, p_T} p_C$, and $p_C \geq 0$ is redundant. Thus, setting $p_C = \underline{N}$ and $p_T = 0$ is optimal. **Q.E.D.**

Intuitively, to ensure that F does not choose continuation after R exerted the undesired broad effort e_B, the contract requires F to pay the gain from continuation after e_B, $\underline{N}$, upon continuation. Hence, choosing continuation does not pay off for F. 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, termination is not attractive unless F sets a high continuation price. Similarly, to ensure that F continues after R exerts the desired effort e_N, an optimal contract requires F to pay more than the gain from termination. However, in this simple setting, there is no gain from termination (F has zero outside benefits), and thus it suffices to set $p_T = 0$.

Denote the option contract $(F, \underline{N}, 0, N, N+B)$ as $\hat{A}_O$. F's payoff from $\hat{A}_O$ is $\hat{\Pi}_O = \overline{N} - \underline{N} - I$, and R's payoff is $\underline{B} + \underline{N}$. We can now characterize the conditions under which F prefers $\hat{A}_O$ to the best possible no-option contracts, A^*_{NO}, i.e., $\hat{\Pi}_O > \Pi^*_{NO}$.

Lemma 3. *F's payoff under contracts in* $\hat{A}_O$ *is strictly higher than the payoff under contracts in* A^*_{NO} *iff* $\overline{N} - \underline{N} > \max\{\underline{N}, I\}$.

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

Lemma 3 says that the option contract is more likely to improve over the best no-option contract the larger the difference $\overline{N} - \underline{N}$ is. That is, if exerting e_N rather than e_B significantly increases the narrow surplus, it is worth to induce e_N at the cost of paying a positive p_C.

So far, we have shown that the option contract $\hat{A}_O$ induces *R* to exert e_N (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) with payoff Π_O and show:

Proposition 2. *No other option contract* A_O *increases F's payoff beyond the highest no-option payoff* Π^*_{NO} *by more than* $\hat{A}_O$*, i.e.,* $\Pi_O \leq \max\{\Pi^*_{NO}; \hat{\Pi}_O\}$.

Proof. See Appendix B.

Proposition 2 implies that no other option contract leads to a higher payoff than $\hat{A}_O$ whenever $\hat{A}_O$ is preferred to the unconditional contract. It is, however, possible that other option contracts guarantee *F* the same payoff as contracts in $\hat{A}_O$.

Thus, in the simplified setting, option contracts allow *F* to extract more surplus. Hence, we predict the use of option contracts when research effort is not contractible. But we cannot predict the exact type of option contract that should be observed. Several types of option contracts (as discussed in the proof of Proposition 2) are payoff-equivalent.

The payoff equivalence disappears when we depart from the (unrealistic) assumption that *F* has benefits neither from *B* and nor, in case of termination, from *N*.

III.2. Extended set-up: F has outside options

We now turn to the more realistic assumption of positive outside benefits. That is, *F* can extract a portion ε, $\varepsilon \in (0,1)$, of the broad surplus *B* (if assigned the broad property rights) and, after termination, a portion α, $\alpha \in (0,1)$, of the narrow surplus *N* (if assigned the narrow property rights). As before, *F* extracts the full narrow surplus *N* under continuation (if granted the narrow rights). For simplicity, we focus on the case[14]

[14] This assumption simply reduces the number of cases to be considered (see Appendix B). It guarantees that, when *F* gets the broad rights, the value of *B* to *F* is always less than the minimal amount *R* requires to contract with *F*, i.e., *R*'s outside option value,

$$\underline{B} > \varepsilon \overline{B}. \qquad \textbf{(A.4)}$$

Figure 2.b summarizes the payoffs of both parties under continuation or termination and different intellectual property (IP) rights allocations in the generalized case. As in the simplified case, *F*'s has to pay $\underline{B}$ to *R* if *R* does not obtain broad property rights and 0 if *R* obtains at least the broad rights. Plugging the minimum price into each of the eight contract scenarios (rows of Figure 2.b) and maximizing *F*'s payoff over *e* and across the different contract scenarios, we find that, as before, *F*'s payoff is maximized under $e = e_N$, continuation, and $o_C = N$, resulting in a net payoff of $\overline{N} - I$ for *F* and of $\underline{B}$ for *R*.

The results under contractibility and limited contractibility without option contracts are unchanged: *F* obtains the maximum payoff $\overline{N} - I$ if *e* is contractible and $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$ if *e* is not contractible and option contracts are not permitted. If *e* is not contractible and option contracts are permitted, we can show that Lemmas 1-3 generalize as follows:

Lemma 1′. *An option contract 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. See Appendix B.

Compared to the simplified set-up, the lower bound of the price range becomes smaller the larger α and ε are. Thus, option contracts with $i = F$, $o_C = N$, and $o_T = N + B$ that implement e_N and continuation are less costly than in the simplified setting for two reasons: *F* does not lose as much from termination, and the allocation of broad rights can be used to make the threat of termination less costly to *F*. We can now characterize the optimal prices within the class of contracts satisfying (1′). 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. Lemma 2 generalizes as follows.

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

$$p_C \begin{cases} = \Delta \\ = 0 \\ = 0 \end{cases} \quad \textit{and} \quad p_T \begin{cases} = 0 & \textit{if } \Gamma > \Delta \geq 0 \\ \in [0, -\Delta] & \textit{if } \Gamma > 0 > \Delta \\ \in (-\Gamma, -\Delta] & \textit{if } 0 \geq \Gamma > \Delta \end{cases} \qquad (2')$$

maximizes F's payoff.

Proof. See Appendix B.

Figure 3 provides an illustration. Intuitively, Γ and Δ capture the differences in *F*'s payoff in case of continuation (relative to termination) if *R* chooses e_N or e_B respectively. To ensure that *F* does not choose continuation after *R* exerts 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 such a contract is not possible, termination is not attractive unless F sets a positive continuation price. Similarly, to ensure that F continues after R exerts the desired effort e_N, an optimal contract requires F to pay more than the gain from termination, $-\Gamma$, upon termination (if there is a gain, i.e., if Γ is negative).

We now denote with $\hat{A}_O$ all option contracts (F, p_C, p_T, N, $N + B$) satisfying (2′). F's payoff from any contract in $\hat{A}_O$ is $\hat{\Pi}_O = \overline{N} - \max\{0, \Delta\} - I$, and R's payoff is $\underline{B} + \max\{0, \Delta\}$. Lemma 3′ states 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 second-best no-option contracts, A^*_{NO}.

Lemma 3′. *The payoff of F under contracts in* $\hat{A}_O$, $\hat{\Pi}_O$, *is strictly higher than the 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 $\hat{\Pi}_O > \Pi^*_{NO} \Leftrightarrow \overline{N} - I > \max\{0, \Delta\} \Leftrightarrow \overline{N} - I > \Delta$, 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′ shows that, with $\alpha > 0$ and $\varepsilon > 0$, the profitability of an option contract, relative to a no-option contract, depends not only on how much e_N increases N relative to e_B, but also on F's outside options in case of termination. 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. As a result, a stronger version of Proposition 2 holds in the set-up with positive outside options:

Proposition 2′. *No other option contract increases F's payoff as much beyond the highest no-option payoff* Π^*_{NO} *than contracts in* $\hat{A}_O$, *i.e.,*

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

Proof. See Appendix B.

The crucial difference between Proposition 2′ and Proposition 2 is that, whenever $\Pi^*_{NO} < \hat{\Pi}_O$, the payoff Π_O from any alternative option contract is strictly smaller than the payoff $\hat{\Pi}_O$ from option contracts in $\hat{A}_O$, rather than only weakly smaller. Thus, 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 observe either the unconditional contract or $\hat{A}_O$, but no other option contracts. This result implies the following empirical prediction:

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

The model illustrates that the incentive conflict between the financing firm and the research firm may prevent the parties from entering research collaboration whenever research activities are not contractible. The parties can overcome this problem using an option contract. However, to prevent opportunistic exercise of the option right to terminate payments, conditional on termination need to be specified. Given the financial constraints of the research firm and the required difference between continuation and termination payments, the financing firm may not extract the full profit $\overline{N} - I$. In other words, the preferred option contract is costly relative to the first-best outcome when e is contractible.

III.3. Set-up with no financial constraints

We now introduce financially unconstrained firms into the model to illustrate that the relationship between option contracts and contractibility does not hold. We assume that, as before R requires funding I at $t = 1$, but is liquid at $t = 2$ so that prices p_C and p_T can be negative.[15]

To show that Prediction 1 does not hold with liquid firms, we consider the case where it is socially optimal to implement e_N, i.e., $\overline{N} + \underline{B} > \underline{N} + \overline{B}$. Lemma 1′ does not depend on the non-negativity constraints on p. Thus, as before, e_N can be implemented using an option contract with $i = F$, $o_C = N$, and $o_T = N + B$ and prices p_C and p_T such that $(1-\alpha)\overline{N} - \varepsilon\underline{B} > (p_C - p_T) \geq (1-\alpha)\underline{N} - \varepsilon\overline{B}$. However, F can now set $p_T < 0$ if necessary to satisfy double-inequality (1′):

Lemma 2′′. *In the set of option contracts* $(F, p_C, p_T, N, N + B)$ *that implement* e_N*, setting* $p_C = 0$ and $-\Gamma < p_T \leq -\Delta$ *maximizes F's payoff.*

Proof. With $p_C = 0$ and $-\Gamma < p_T \leq -\Delta$, e_N is implemented by Lemma 1′. Since R's equilibrium payoff under this contract is its reservation utility $\underline{B}$, F's profit cannot be increased further. **Q.E.D.**

An immediate implication of the Lemma 2′′ is that the option contract maximizes F's payoff also if research effort is contractible: it achieves the maximum joint payoff for R and F while paying R just its reservation utility. Hence, in contrast to the setting with constrained firms, the use of option contracts is not predicted to be correlated with contractibility. Rather, it is optimal even if research effort is contractible.

[15] R may become liquid due to the technology developed in $t = 1$ or inflows from other projects. Assuming that R is illiquid ex ante, but liquid ex interim (rather than assuming that R is liquid throughout) allows us to mirror the previous analysis: Research requires F to contributes initial funding and motivates the research collaboration.

A second difference in results regards the type of option contract. If R is liquid, F can obtain the maximum payoff also with option contracts that do not involve reversion of broad property rights upon termination, e.g. (F, p_C, p_T, N, $\varnothing$). (See Lemmas 1‴ and 2‴ in Appendix B.)

We conclude that the use of option contracts co-varies with the contractibility of research efforts for financially constrained firms but not necessarily for liquid firms. If a research firm is financially unconstrained, different types of option contract as well as other, unconditional contracts allow the financing firm to extract the full surplus. Thus, the option contract may or may not be employed, regardless of the contractibility of research efforts:

Prediction 2. While research agreements with financially constrained research firms employ the option contract only if research is non-contractible, research agreements with liquid research firms may employ the option contract with or without research contractibility.

IV. Data

To test the predictions of the model we collected a novel data set of research agreements. We sought to employ as large a sample of biotechnology research agreements as possible, in which the financing firms are either pharmaceutical or (larger) biotechnology firms.

Our main source is a database compiled by Recombinant Capital (ReCap), a San Francisco-based consulting firm that tracks the biotechnology industry since 1988. The data is typically licensed by major pharmaceutical, accounting, and law firms for a considerable annual fee.

Most contracts in ReCap's data are with publicly traded research firms. Public firms are required by the SEC to disclose material transactions, and agreements representing 5% or more of a firm's revenues are typically considered material. Since most research firms have modest revenues, this criterion is often triggered. (The larger financing firms rarely file research agreements.) Biotechnology firms tend to interpret the requirement conservatively and report not only the fact that they enter into strategic alliances, joint ventures, and licensing agreements, but file the contracts as amendments to 10-K, 10-Q, S-1, or 8-K statements.

Not all filings are by public firms. Research firms that subsequently go public (or file to go public and then withdraw the offerings) typically disclose research collaborations signed earlier that are still active. In addition, a number of states require privately held companies with employee stock option plans to file material documents.

Recombinant Capital seeks to create as comprehensive a data set as possible of the agreements in the biotechnology industry, based on SEC and state filings, news accounts, and press releases. ReCap summarizes the basic information on all identified agreements, including the par-

ties, the date of the agreement, the stage of the lead product at the time of signing, and the technologies and diseases that are the focus of the agreement.

For a subset of the agreements that have been filed in a public document (rather than simply alluded to in a press release or a security filing) ReCap obtains more detailed information. The (time-consuming) initial coding is often done at the request of clients. For example, a client may request that a number of transactions in a given technology or by a certain firm be analyzed. In other cases, ReCap analyzes agreements at its own expense. These tend to be particular "significant" agreements, either in terms of the science or the magnitude of the contractual payments.

An important question is what type of selection bias ReCap's procedure creates. A primary bias appears to be that, since well-established and scrutinized research firms are over-represented, the types of information problems we highlight in this paper are less likely to be present. Thus, the sample is likely to under-represent the importance of these issues.

Based on the full ReCap database, we construct our sample using the following procedure, summarized in Table 1. We start from the set of all analyzed agreements through the end of 2001. We eliminate transactions that did not involve a biotechnology company as the research firm (overwhelmingly, these are agreements with universities, non-profit, government bodies, and hospitals and a few cases of agreements between two pharmaceutical firms[16]), those without research and product development components (i.e., contracts that do not fall into at least one of the ReCap classes "Collaboration," "Co-Development," "Development," and "Research"), renegotiations or extensions of existing agreements (i.e., using again the ReCap classification scheme and the actual text of the analysis, we determine if the two parties had a previous research collaboration covering the same set of technologies), contracts involving three or more independent parties (determined from the text of the agreements), and agreements where the financing firms held at least a 50% stake in, or a purchase option for, the research firm at the time the agreement was negotiated (determined through a review of securities agreements). We also eliminate three agreements that appear twice in the ReCap database and one agreement that was subsequently dropped from the database. The resulting sample consists of 580 contracts. We carefully examine the contracts and code the key features relevant to our analysis (see discussion below).

Table 2 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.

[16]We focused on (non-subsidiary) biotechnology firms as identified by ReCap and the industry classifications in two major databases of high-technology firms, Venture Economics (classes 4100 to 4390 and 4600 to 4900) and VentureOne (classes 2300 to 2499), which track firms backed by angel investors, corporate sponsors, and venture capitalists. As a diagnostic check, we examined whether the list of biotechnology firms would change when we used another source. We compiled the names of stand-alone firms dedicated to biotechnology listed in the various editions (through 2001) of the *BioScan Directory*, but found few differences.

The research firms in the agreements differ substantially in their research capabilities. For instance, there are sharp differences in the seasoning of the key executives and the scientific reputation of the advisors. These quality differences will be important to control for but are difficult to parameterize. Following previous literature, we use the reputation of the investment bank who takes a biotechnology firm public: all else being equal, a biotechnology firm underwritten by Morgan Stanley is likely to be a higher-quality firm than one taken public by D.H. Blair. We use the investment bank ratings compiled by Carter and Manaster (1990), Carter, Dark, and Singh (1998), and Loughran and Ritter (2004) from the time when the firm went public. If no rating is available for that period, we employ the rating in the most proximate period. We determine ratings for 526 firms in our sample, ranging from 1 to 9 with a median of 8.75.

The focus of our analysis is to relate the differences in contract design to differences in the contractibility of the research activities. To measure variations in contractibility we rely on ReCap's description of how concretely the main research target is specified. Our primary distinction 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, it is hard to specify the exact research tasks and, hence, the contractual partners cannot deal with the cross-subsidization problem directly, in the form of contingent contracting.

While we rely on ReCap's classification of contracts with and without a pre-specified lead product candidate, the distinction is rather apparent from the language in the contracts. Research agreements that lack a specific compound or process are vaguer and involve a broader "discovery" phase. We illustrate the distinction with four examples from the "Field of Use" section or preamble of the contract (as specified by ReCap), which define the scope of the collaboration. Agreements that build on 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. As shown in Table 2, the lead product is not specifiable in 37% of our observations, and for 11% we cannot determine whether it is specifiable. We have also considered 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.

Table 2 also shows some summary data on other characteristics of the research agreements. We identify contracts with diagnostic and veterinary products (13% and 5%) since the scientific and regulatory uncertainties are considered to be lower than for therapeutic products. We also separate out biotechnology financing firms (17%), who may employ different contracts. Most research firms have only very modest revenues and financial resources, though there are a few positive outliers. One useful summary statistic, denoted as "Financial Health Index," is defined as the ratio of the absolute value of the firm's cash flow (or, if unavailable, net income) to its cash and equivalents. It is the inverse of what venture capitalists often refer to as the "fume date"—the time until the firm will run out of financing if it continues to consume cash at the same rate and does not receive additional financing. If the firm has non-negative cash flow, the index value is set as zero. We also identify, in the U.S. Patent and Trademark Office database, the number of patents awarded to the research firm by the time the research agreement is signed.

V. Empirical Analysis

The focus of our empirical analysis is the contractual response to the contractibility of research. Before we begin this analysis, we examine the empirical validity of two assumptions that underlie our multi-tasking model.

V.1. Evidence on scientific orientation and multiple projects

The ability of researchers to multi-task gives rise to conflicts in two ways. First, even for a given research project, researchers may emphasize more academic aspects and tests. Second, researchers might work on different projects, either with other collaborators or as stand-alone projects.

To test whether research firms are more oriented to academic science than the financing firms, we compare the patented research of both parties. We measure which research is more scientific by examining the citations to non-patented prior art, which in these awards are overwhelmingly to articles in scientific journals.

To implement this analysis, we randomly choose 100 contracts in our sample. For each party, we retrieve the first patent applied for in the month of the contractual agreement.[17] As a

[17] If a party made no application in that month, we use the first application in the year. If there was no patent application in that year, we use the first application in the prior year or, if there was none in the previous year, in the year after the research agreement.

baseline (placebo) test, we first compare citations of other U.S. patents. These rates should not differ unless the parties differ in citation proclivity more generally. (For instance, smaller companies are more likely to rely on outside counsel to prepare their patent applications, who may be more scrupulous in their citation practices than internal staff.) We find that patents of research firms contain on average 11.8 citations to other patents while the average for financing firms is 10.0. In a paired t-test, the means are not significantly different at conventional confidence levels.

We then compare citations to non-patented prior art. The typical patent of a research firm makes 26.9 such citations, while the mean is 13.7 for financing firms – about half as many. The means are significantly different at the 1% confidence level. Thus, the citation practices indicate that research firms rely more heavily on scientific research.[18]

Second, we examine whether the research firm is juggling multiple projects by collecting data on all the research agreements that the firm had entered into with other firms in the three years prior to the research agreement in question. We use three years since earlier work suggests that is the median alliance life-span.[19] We find that the research firms in our sample engaged in a mean of 6.4 and a median of 4 such research agreements in the previous three years.

We also examine the number of agreements in technologically similar areas. ReCap lists up to six broad classes of technology (such as "Drug Delivery" or "Immunoassay") for each research agreement. We define a prior agreement as "technologically similar" if one or more of these classes overlap. We find a mean (median) of 4.8 (3) overlapping research agreements.

V.2. Analysis of termination and broad intellectual property rights

We now analyze how the contract design responds to the degree of contractibility. As the outcome variable, predicted by our model, we wish to determine whether the financing firm is granted the unconditional right to unilaterally terminate the agreement and obtains broad rights to the product upon termination.

A wide variety of clauses allow the financing firm to terminate the agreement. However, most of them are conditional on specific events, such as bankruptcy or acquisition of the research firm. We identified three cases where the financing firm can terminate the agreement unconditionally, as predicted by the theory for cases of non-verifiable research effort:

1. The financing firm can terminate 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.
2. The financing firm can terminate the agreement for "misbehavior" or "breach."
3. The financing company believes the continuation of the collaboration would be "unwise."

[18] The results are almost identical (a little more significant) with unpaired tests, which allow for slightly larger samples.
[19] See Lerner, *et al*. (2003).

Note that, in theory, the second 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." In practice, however, termination for "material breach" functions much like an open-ended termination. It allows the terminating party to employ various self-help remedies unless and until the other party goes to court to litigate the issue. In addition, the burden is on the non-terminating party to show the termination was not justified.[20]

The bottom rows of Table 2 show that termination rights are a widespread feature. In almost all contracts some kind of termination right is specified (97%) and is assigned to the financing firm or both parties (96%). 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% of the sample, unconditional termination rights are coupled with broad access to the intellectual property in case of termination. The latter contract design conforms exactly to the prediction of the theory: it excludes the research firm from retaining the value generated during the collaboration in case of termination. The model predicts that, while patents and other intellectual property rights are arguably worth more in the hands of the research firm, the threat of reassigning them to the financing firm ensures profit-maximizing research of the biotechnology researchers. Note that the 11% frequency likely understates the overall empirical importance of this type of contract design since our data, which relies on publicly filed documents, disproportionately samples larger research firms. The incentive and contractibility problems highlighted in the paper are less likely to bind in these more liquid firms than in the overwhelming majority of small, non-public research firms (Proposition 2). [21]

Based on those clauses, we construct the dependent variable in several ways. We use both a binary variable, which indicates if the financing company has at least one unconditional termination right, and an integer variable, which counts the number of termination rights of the financing company from 0 to +3. In both versions, we require that the financing party also obtains broad intellectual property rights upon termination. Alternatively, we consider only cases where the financing firm has the right to terminate (with broad rights) and the research firm has no right to terminate (with or without broadened rights). Again, we construct both the simple binary variable, which takes the value of 1 if the financing firm has at least one termination right and the research

[20] 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).

[21] Even if these terms were used only in 11% of the sample, they would be of significant practical importance. About 700 biotechnology alliances were signed in 2005, with an estimated total value (the sum of promised pre-commercialization payments) of $56 billion. In eight of the top ten biotechnology drugs in $2005, a strategic alliance played a key role in the development. Cumulative 2005 sales of these eight drugs were $23.3bn. (Source: http://www.recap.com/consulting.nsf/0/3545FA9FCBB76CEB8825719A007FB35C/$FILE/McCully_UCSC%20Extension%200606.pdf, plus the authors' analyses of the ReCap database.)

firm has none, and as well as integer variables with values from –3 to +3, counting the "net" termination rights of the financing firm minus those of the research. All approaches deliver approximately the same results.

We begin by testing Prediction 1: Are agreements about projects without a contractible lead product candidate more likely to grant the financing firm the right to terminate the collaboration and broad access to the intellectual property involved?

We first present a series of simple univariate comparisons (Panel A of Table 3). Agreements are significantly more likely to assign termination and broad property rights to the financing firm when there is no specifiable lead product candidate at the time the agreement is signed, as predicted by our model. This type of contract design is also more likely when the agreement does not involve veterinary and diagnostic products (which, as noted in Section IV, are likely to have substantially reduced information problems) and when the agreement is between two biotechnology firms, though the differences in frequency are typically insignificant. The differences are also insignificant between firms with high and low net income. Firms that are ultimately underwritten by high-status underwriters are more likely to employ the termination and broad rights clause than those with low-status underwriters, though the p-value of the difference is 0.11.

In Panel B, we show cross-tabulations for the latter two subsamples of high- and low-net income firms and of firms with high-status and low-status underwriters. (Later in the paper, we undertake formal tests of differences-in-differences.) We find that the differences in contract design between projects with and without specifiable lead product are statistically significant for low net-income but not for high net-income firms and for firms with high-rank underwriters but not for firms with low-rank underwriters. The first result is suggestive evidence supporting our model of the contract design: the use of option contracts is predicted to be negatively correlated with contractibility (Prediction 1), but we have no prediction for financially unconstrained research firms (Prediction 2). The second result suggests that the use of option contract is not a response to dealing with low-reputation or less capable research firms.

We now turn to the econometric analyses. The baseline regression analysis is reported in Table 4. We test whether the number of unconditional termination rights (combined with the assignment of broad intellectual property rights to the financing party in case of termination) is positively related to the lack of specified lead products. We employ a variety of control variables:

- To account for a possible time trend in the transactions, we control for the date of the agreement. We initially employ a continuous date variable and later year fixed effects.
- We include dummies for diagnostic and veterinary products, and the underwriter rank.
- We also identify, in the U.S. Patent and Trademark Office database, the number of patents awarded to the research firm by the time the research agreement is signed. As dis-

cussed in more detail below, the cross-subsidization problems may be more severe in research firms that hold many patents, indicating numerous related research avenues.

- To control for capital constraints, we use the "Financial Health Index" defined above.
- We include the number of previous research agreements between the same parties. Prior interactions may allow firms to accumulate reputational capital and ease the contracting.

The table presents a number of regressions, which use some or all of these independent variables, trading off completeness and sample size or selection. (The lower half of Table 1 documents how the use of different control variables affects the sample size.) We employ both ordered logit and ordinary least squares (OLS) specifications. The ordered logit is more suitable given reflect the ordinal, non-negative nature of the dependent variable, though the estimation fails to achieve convergence in smaller subsamples or after including a large number of controls. Finally, we employ fixed effects for the thirteen most frequently represented financing firms in addition to the year fixed effects. The firm dummies are created for the entities that entered into the agreement, even if the firm was subsequently merged or acquired (e.g., American Home Products or Sandoz).[22]

Columns 1 and 2 present the ordered logistic estimations, with the reduced and the full set of control variables, respectively. In both specifications, we estimate a coefficient of 0.68, significant at the 5% confidence level. Hence, if an agreement does not specify the lead product the odds of having termination rights with broad property right reversion over the odds of having none increases by 97% (compared to an agreement with specified lead product), consistent with the raw statistics in Table 3, Panel A. The estimated odds ratio is larger than the "raw" odds ratio: the frequency of contracts with at least one unconditional termination right (broad property rights) is 15% among contracts without specifiable lead product and 9% otherwise, resulting in an odds ratio of 1.72. All other coefficient estimates are highly insignificant.

We observe a consistent pattern in the OLS estimations (and many dozens of similar unreported analyses). The estimated effect of not having a specifiable lead product is 0.13 when including the full set of controls and 0.14 when using all controls and year fixed effects instead of the continuous date variable. This result is not only statistically, but also economically significant, relative to the mean of the dependent variable (0.15).[23] Thus, regardless of the estimation method and specification, we find that research collaborations in which the research task is hard to contract on (due to the lack of a specifiable lead product) are associated with a significant increase in the termination and broadened intellectual property rights assigned to the financing firm.

[22] In addition, we re-ran the fixed-effects regression adding a dummy variable for the thirteen most represented financing firms, using the entity name as it existed in 2003. Thus, we coded the Novartis dummy variable as one whether the alliance was entered into by Ciba-Geigy, Novartis, and Sandoz. The results were essentially unchanged.

[23] The R^2 is similar to other empirical work analyzing non-standardized contracts, such as Robinson and Stuart (2007).

As in the logistic analysis, all other explanatory variables have little predictive power. While the poor power of controls might reflect, at least in part, the imprecision of these measures, it is surprising that we fail to estimate any significant effects across all specifications. It should be noted, however, that in many instances, the year and financing company fixed effects are statistically significant. Moreover, the lack of explanatory control variables with high statistical power is rather common in the empirical analysis of real-world and non-standardized contracts.[24]

A natural concern in this analysis is endogeneity. For instance, a major issue that affects the entire empirical literature on (research) alliances is the (endogenous) choice to sign a contract. Financing firms entering into research alliances are likely to be different from those not entering. These differences may affect the observed contract design. While there is no obvious reason why the endogenous entry decision would affect the relationship between specified lead products and option clauses, we attempt to address the selection issue directly. In particular, we would like to make sure that our results are not driven by endogenous matching between low-ability research types and financing firms who (opportunistically) insist on termination rights.

A first step towards addressing these concerns is the inclusion of firm dummies in the estimation reported in Column 5 of Table 4. The inclusion of dummies for the thirteen most frequently represented financing firms, while jointly significant, has little impact on the other coefficients. In particular, both the statistical and the economic magnitude of the coefficient of interest, the estimated effect of "no specifiable lead product," are unaffected compared to the regression including only year fixed effects. These results support the interpretation that, for a given financing firm, the variation in termination and broad intellectual property rights is indeed related to the research program. The results also alleviate the larger endogeneity concerns pointed out before: The occurrence of different types of contracts within the same financing 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.[25]

We will further address the concern about endogeneity and omitted variables below, when testing Prediction 2 and comparing the results on various subsamples. Before turning to the second set of results, however, we perform several empirical tests to evaluate more closely our proxy for "non-contractibility of research," the lack of a specifiable lead product candidate. The proxy is constructed to capture contracting situations, in which it is hard to describe and verify the tasks to be performed by the research firm. Such situations are problematic if the researchers have incentives to take the financing firm's funds but work on different tasks.

[24] For example, in Banerjee and Duflo [2000], none of "contract" and "project characteristics" are significant in the eight regressions in the primary table analyzing contract design (Table III), and only one of the controls for "firm and client characteristics" is significant (and then in only three regressions.)

[25] In unreported analyses, we repeat the regressions, clustering the standard errors in the analyses by research firm. This modification has little impact on the results.

One way to test our interpretation is to construct an alternative and more direct proxy of the research firm's incentives to work on different tasks. So far, we are only indirectly measuring research firms' incentives for "project substitution." As a direct measure, we examine whether research firms are indeed involved in multiple projects concerning the same technology and test whether the contract is designed differently when the firm has more outside projects.

To determine whether a research firm was engaged in juggling multiple projects, we construct a proxy using data on all other research agreements that the company had entered into or filed.[26] As above in Section V.1, we restricted our searches to agreements in the three years prior to the contract in our sample. The summary statistics of the alternative proxy are in the lower half of Table 1 (and are discussed above).

The first two columns of Table 5 show the results of our analysis. In Column 1, we use the new count measure as an alternative proxy for contracting problems. We include the full set of controls as well as year and firm fixed effects. We find that the proxy is associated with a significant increase in the probability that the financing firm receives unilateral termination rights combined with the broad intellectual property rights in case of termination. As before, all other controls are insignificant. Thus, we replicate our main result using the alternative measure.

In Column 2, we include this proxy along with our measure of "no specifiable lead product." Here, our baseline measure remains economically and statistically significant, while the new proxy becomes insignificant. We obtain similar results (i) when restricting the count to research agreements in similar technologies (defined as being classified by ReCap into the same technology classes), (ii) when also using research agreements signed in the three years after the sample contract was signed (on the grounds that they might also introduce contracting challenges, and might have been at least partially anticipated), and (iii) when using cross-tabulations rather than regressions. Hence, our empirical proxy appears to capture the multi-tasking problem laid out in the theoretical analysis.

A second set of tests addresses the concern that the measure of "no lead product" may identify otherwise different contract situations. For example, in agreements without specifiable lead product the financing firm might contribute more than money, e.g., knowledge or methods as noted in the ALZA case. Those cases might be more comparable to a large firm subcontracting research with a specialized firm, which could explain the different contract design.

To address this concern about unobserved heterogeneity, we restrict the sample of contracts in several ways. First, we examine whether the financing firm appears to have technological

[26] We also attempted to measure incentives for project substitution by examining the total number of projects, as well as the progress of their drugs through clinical trials. Unfortunately, neither of the two main data sources, the "Clinical Trials" section of the ReCap database and PharmaProjects, permits such an analysis, mostly due to missing dates.

know-how in the area of the contracted research. We focus on patented research. To identify patents that indicate technological know-how related to the research agreement, we extract a set of keywords for each contract from the short contract description prepared by ReCap. This description is typically based on the introductory paragraphs of an agreement, which define its scope. More precisely, we tabulate all words in the text strings of the descriptors by frequency and retain those words and abbreviations that describe either a disease or technology.[27] We then search for U.S. patent applications by the financing firm that either contain all of or any of the same keywords in the patent abstract. We search the U.S. Patent and Trademark Office data, which records all patents awarded from 1976 onwards,[28] for patents that the financing firm had already applied for at the time of the research agreement. One subtle issue is whether one counts patent applications of the firm itself or also those of firms with which it had merged by the time of the research agreement. In the reported results, we include the research of the merged entities. (To identify the patent applications of those firms, we retrieved the history of all mergers and acquisitions for over the period 1975-2001, using the SDC Mergers and Acquisitions database. All results are robust to examining just the activity of the firm itself.) In each case, we only employ patent applications that were ultimately issued: for the bulk of the period under study, the U.S. Patent and Trademark Office did not disclose unsuccessful patent applications.

Columns 3 and 4 of Table 5 show the results when we eliminate contracts where the financing firm had already-filed patent applications with the same keywords. In the third column, we eliminate contracts where patent applications had *any* of the same keywords; in the fourth, we eliminated the smaller number where a filing had all of the keywords. In each case, the results go through as before. We did a larger number of robustness checks, such as cross-tabulations and using different searches (for instance, altering the keywords employed, the sections of the patents to search, and the patents examined), and consistently found that the cases where the financing firms had significant technological capabilities were little different from the others in this regard.

We also addressed this concern by examining the responsibilities delineated in the contracts themselves. We employ two approaches. In Column 5, we report the results of an analysis where we eliminated agreements classified by ReCap as "joint ventures," "joint R&D," and "collaborations." In Column 6, we report the results of an analysis based on our own reading of the contracts. We classify the agreements into those where the role of the financing firm is unambiguously only providing financing (214 cases), those where there is a role in the research process (150), and those where a determination could not be made with certainty (216). In the reported regression, we eliminate observations where the financing firm unambiguously played a role in

[27] As a robustness check to this mechanical strategy, we assigned the task of identifying disease and technology keywords in the descriptions to two biology students. The resulting lists of keywords were remarkably similar.

[28] The USPTO patent database can be accessed at http://appft1.uspto.gov/netahtml/PTO/search-adv.html.

the research process. In both Columns 5 and 6, we find that even after these observations have been eliminated, a strong relationship remains between a non-contractible lead product and the assignment of unilateral termination and broad intellectual property rights to the financing firm.

The final two columns of Table 5 address the heterogeneity concern by eliminating agreements about diagnostic and veterinary products, which may be different, e.g., due to the expedited review process (Column 7), and by adding controls for the various diseases that are the subject of the agreement (Column 8). (In the reported regression, we employ the disease classifications undertaken by ReCap, but the results are robust to using our own, more detailed scheme, which we constructed with the help of two medical doctors). In both cases, the results are robust.

V.3. Additional predictions

Financial constraints. We now test Prediction 2 and examine the impact of financial constraints on the contract design. As discussed in Section III.3, our prediction about contract design depends on the assumption of an illiquid research firm. If the research firm is liquid, option contracts may be observed both when research is contractible and when it is not, or they may be used in neither case. Hence, we do not have a theoretical prediction for the subset of liquid research firms.

Prediction 2 implies, therefore, that we should perform our core test only in the subsample of financially constrained firms. Since we do not have a perfect measure of constraints and since research firms are generally considered to be illiquid, we started with the overall sample. Our data is peculiar, however, in that many research firms have gone public. Large and established firms may be significantly less constrained than a biotechnology start-up firm. In the second step of our analysis, we thus reestimate on the most constrained subset of firms.

To identify research firms that are constrained, we examine their net income in the year prior to the research collaboration. (We employed a similar approach in the cross-tabulations reported in Table 3, which corroborated the predicted pattern.) Cases where the research firm has net income above and below that of the median firm (in 2002 dollars) are considered separately.

In the regressions reported in Columns 1 and 2 of Table 6, below-median firms display a statistically significant relationship between the provisions of termination and broad intellectual property rights and contractibility. For above-median firms, the coefficient is roughly half the size and insignificant. The differences between the coefficients are not statistically significant at conventional confidence levels. It should be noted, however, that only the coefficient in the low net-income sample is relevant. We do not have a prediction for the high net-income sample. While the lack of significance is interesting, it neither confirms nor contradicts our theory.[29]

[29] It is possible, however, that variations of our model would predict significant differences. That is, one could introduce frictions or transaction costs arising from option contracts into the model, and in that case the theory would indeed predict significant differences.

We find the same basic pattern when we add a variety of fixed effects (Columns 3 and 4). In Column 5, we estimate pooled regressions that include all observations. We first repeat the financial constraints analysis with separate dummy variables for research firms above and below the median net income, as well as interactions between the dummies and the indicator of "no specifiable lead product." Only the interaction term with financially constrained firms is significantly positive. But, once again, we cannot reject the hypothesis that the coefficients are identical.

In unreported regressions, we explored the robustness of these results to other definitions of capital constraints. When we isolated more extremely constrained subsets of firms, such as firms in the bottom quartile of net income, the results become even sharper. Also, when we divide firms on the basis of cash and equivalents, the results are qualitatively similar, though the divisions are weaker. This may reflect the fact that cash is a worse proxy for financial constraints among biotechnology firms. In many instances, firms do not raise their financing all at once, but in a series of offerings. Thus, a firm with a strong investor clientele may have access to the capital markets even though its cash in hand is relatively modest.

Outside options. Another implication of the theory is that the option contract is more attractive for financing firms with higher ex-post outside options. The more profit the firm can extract in the case of termination (both from the narrow envisioned research and the broader side products), the more valuable the termination option and the larger the threat of termination for the research firm.

Unfortunately, outside options are hard to measure. One potential indicator is whether the financing firms is a biotechnology company. Biotechnology firms that have grown large enough to provide financing in research collaborations are likely to have more research capacity to use the patents for future projects. In terms of the model, α is likely to be large. On the other hand, pharmaceutical firms also invest in developing internal biotechnology research capabilities.

In an unreported analysis, we split up our sample contracts between a pharmaceutical and a biotechnology firm (442 cases) and those between two biotechnology firms (84 cases) and rerun the regressions of Table 4. The coefficient on "non-specifiable lead product" is consistently larger for the biotechnology-biotechnology contracts than for the others, though in some cases the differences are modest. The differences are never significant and, thus, at best suggestive.

V.4. Alternative explanations

We now return to the broader concerns about the interpretation of our proxies and 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 researchers. When entering the agreement, the financing firm cannot perfectly assess the abilities of the researchers and the chances of

a successful collaboration. Termination rights allow the financing firm to end the relationship as soon as it recognizes the research partner to have low abilities. In other words, the "unspecified lead product" variable may capture uncertainty about research abilities or collaboration success.

In order to address this adverse selection concern, we attempt to control for research abilities. As mentioned in Section IV, we examine the underwriter who took the research firm public. We anticipate that the higher-quality underwriters indicate higher-quality research firms. Following previous literature, we use a Carter-Manaster (1990) style score to proxy for underwriter reputation. While Table 4 showed that our results are independent of this control, we now run separate regressions for firms ranked above and below the median Carter-Manaster (1990) score. If the difficulty of discerning the research firm's type explained the use of the option contract, the relationship between option contracts and (non-)contractibility should be stronger among the lower-reputation than among high-reputation firms. Above-median firms are not only likely to have better abilities and prospects, but also benefit from the "certification" implicit in the underwriter quality. In other words, the high rank of their underwriter should reduce the uncertainty about their "type" and render the termination and broader access rights more dispensable.

In Columns 1 and 2 of Table 7, we find that the effects are instead larger and significant only among research firms with the highly ranked underwriters. The result is robust to the inclusion of year and firm fixed effects (Columns 3 and 4), though the significance of the coefficient estimate of interest in the high-rank sample diminishes. The same picture emerges in a pooled regression on the full sample, including separate interactions of the high-rank and the low-rank dummies with our lead-product proxy. All results are consistent with the cross-tabulations in Table 3. However, the pooled regression shows that the differences between the subgroups are not statistically significant. Nevertheless, the results reveal that there is no evidence of stronger effects for lower-quality firms, as the alternative hypothesis delineated above suggests.[30]

The adverse-selection story also suffers from failing to explain why the financing firm obtains broader rights. Quite to the contrary, intellectual property produced by "low research types" is likely to be least attractive to the financing firm. Hence, for this alternative explanation to hold, our results would need to be driven by the termination right, not by the broad intellectual property rights. To distinguish between these interpretations, we repeat the analysis above, but use the termination rights of the financing firm (again coded as 0 to +3) as the dependent variable, without requiring the reversal of broad intellectual property rights. In the first four columns of Table 8, we find that, under various specifications, the difficulty of contracting has no significant impact on the assignment of termination rights by themselves.

[30] 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.

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 termination and intellectual property clauses to the lack of contractibility, holding incentive conflicts, informational asymmetry, monitoring costs, etc. constant. Alternatively, variations in the latter variables may determine the contract design. For instance, the parties may employ termination and broad intellectual property rights when they are facing higher uncertainty about the outcome, or whenever the informational asymmetry between the financing and the research firm is higher. To explain our results, these alternative suggestions would need to build on a model where termination and broad rights help to solve the problem, but do so at a cost. The cost may be lower profit for the financing firm (due to financial constraints of the research firm). Or it may be the risk of opportunistic exercise of the termination rights. Then, the termination and broader rights are employed only if the underlying problem (uncertainty, informational asymmetry, or incentive misalignment) is "severe enough."

Before we present additional results that attempt to distinguish between these alternative explanations, 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 taken by the 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 contract design when actions or outcomes are non-contractible.

However, additional empirical results cast doubt on these alternative interpretations. A first indication that uncertainty or informational asymmetry are unlikely to explain our findings is that controls for the type of research program (therapeutic, diagnostic, and veterinary) do not affect the results. 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 intellectual property clauses and therapeutic products. Moreover, even if we eliminate undesired heterogeneity in uncertainty and we examine only agreements focusing on therapeutic products (Table 5, Columns 7 and 8), our baseline results go through as before, with a coefficient of 0.16-0.17 (and a standard error of 0.05-0.06).[31]

Second, we have also already ruled out the interpretation that the financing firm has simply more termination rights in situations with information asymmetries, whether or not broad IP rights reverts. As discussed above, the first four columns of Table 8 show that "termination rights only" are not related to contractibility. Hence termination rights with broadened IP rights do not simply stem from a relation between termination rights and information problems.

[31]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, probably due to the small sample size (less than one-fifth of the observations fall into either of these categories) or because researchers of the financing firm can closely monitor and direct the research activities.

In addition, we undertake a regression analysis employing *specified* termination provisions: that is, those triggered by distinct events such as change in control or bankruptcy of one of the firms or the termination of another agreement by one or both of the parties. As before, we employ as the dependent variable the interaction between a count of the number of provisions present (here between zero and four) and an indicator of broad IP rights reverting to the financing firm. Since our predictions are specific to the combination of unconditional termination rights and broad intellectual property rights, we need to test that not "any" of the other termination rights, combined with broader rights, have a similar correlation with the nature of the research program.

As shown in Columns 5 and 6 of Table 8, the results are quite different from our baseline finding. In transactions without a specified lead product, *specified* termination rights and broad intellectual property rights are not more frequently assigned to the financing firm. This result is consistent with our theory: unconditional termination rights substitute for conditional contracting.

The above results address uncertainty and informational asymmetry. As mentioned before, one may also attribute the correlation between the termination clause and lead-product specifiability to variations in the misalignment of incentives. Research programs with an unspecified lead product candidate may be more likely to imply divergent research interests than those with an agreed on a candidate. Based on our conversations with practitioners, however, the opposite appears to be the case. A biotechnology firm that enters an agreement with a pre-specified and potentially even tested product candidate is more likely to be involved in parallel research collaborations and simultaneous stand-alone research. In other words, the prospect for cross-subsidization may in fact be smaller in collaborations without a specified lead product candidate.

Bargaining power. Another explanation for the contracting pattern analyzed above is the relative bargaining power of the two parties. Research 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 parties directly, and thus cannot reject this possibility with certainty. Some of the evidence presented above, however, seems hard to reconcile with this alternative explanation. Our core result, presented in Tables 4 and 5, appears to be robust across many different specifications with an increasing number of control variables. Some of the added control variables, such as the financing-company fixed effects, are significant; but neither the magnitude nor the significance of the "No specifiable lead product" variable changes. If unobserved differences in bargaining power were behind the estimated effect, the addition of more control variables should lead to the coefficient's magnitude and significance falling. Control variables such as the number of patents of the research firm, its financial strength, and the number of other research agreements should at least partially capture variations in the bargaining power of the research firm, and thereby reduce the partial correlation between the "No

specifiable lead product" variable and the unobserved bargaining power. However, 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 research 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 our key proxy casts doubt on this alternative explanation. On the other hand, we would like to emphasize again that the generally low explanatory power of the control variables limit the viability of this argument. It remains puzzling that other control variables are rarely significant.

In addition, underwriter reputation also serves as a plausible proxy for bargaining power. However, the above results point into the opposite direction: we find the strongest effect for research firms with higher-reputation underwriters and thus, supposedly, more bargaining power.

VI. Conclusion

The design of biotechnology research agreements provides insights into the contractual response to limited contractibility. If the precise task to be performed by one of the parties cannot be specified in the contract, firms respond by assigning unilateral decision rights. Differently from the emphasis on the allocation of asset ownership rights, the parties utilize endogenous decision rights (namely, termination clauses) to solve the problem of contractual incompleteness.

At the same time, there are strong links to the earlier literature on multi-tasking and contractual incompleteness. Part of the contribution of this paper is that it sheds 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 help to better understand 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. The analysis underscores the promise of combining theoretical and empirical approaches to understand contract design.

Appendix A. Notation of Model

R	Research firm
F	Financing firm
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	Narrow surplus, i.e., profits from product targeted in the collaboration.
$\overline{N}$	High value of narrow surplus
$\underline{N}$	Low value of narrow surplus
B	Broad surplus, i.e., profits from other products and collaborations with other firms.
$\overline{B}$	High value of broad surplus
$\underline{B}$	Low value of broad surplus
ε	Share of B that F captures if it has the rights to the broad surplus.
α	Share of N that F captures after termination if F has the rights to the narrow surplus.
p	Payment from F to R
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	$(1-\alpha)\overline{N}-\varepsilon\underline{B}$
o	Property rights assigned to F; equal to ø (no rights), N, B, or $N+B$.
o_T	Property rights assigned to F in case of termination
o_C	Property rights assigned to F in case of continuation
A	Contract or set of contracts between F and R
A^*_{NO}	Set of non-option contracts that maximizes F's profit when e is not contractible
A_O	Option contract, defined by the party i who has the right to terminate prices p_C and p_T and ownership rights o_C and o_T, $A_O=(i,p_C,p_T,o_C,o_T)$
$\hat{A}_O$	Option contract (F, $\underline{N}$, 0, N, $N+B$).
Π	Profit of F
Π^*_{NO}	Profit of F from option contract A^*_{NO}, equal $\max\{\underline{N}-I,0\}$
Π_O	Profit of F from an option contract A_O
$\hat{\Pi}_O$	Profit of F from option contract $\hat{A}_O$

Appendix B.

Proof of Proposition 2.

We consider separately option contracts with $i = F$ and with $i = R$.

(1.) For the class of option contracts with $i=F$, we consider (i) the set of contracts inducing termination in equilibrium, (ii) contracts inducing continuation in equilibrium but with $o_C \neq N$, (iii) contracts inducing continuation in equilibrium, with $o_C = N$ but with $o_T \neq N + B$

(i) F's payoff from any contract inducing termination in equilibrium is $\Pi_O = -p_T - I$ and hence strictly smaller than Π^*_{NO} or than $\hat{\Pi}_O$.

(ii) We can distinguish three types of contracts inducing continuation in equilibrium but not allocating (only) the narrow rights to F after continuation:

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

If $o_C = N + B$, then $\Pi_O = N - p_C - I$, where R's participation constraint implies $p_C \geq \underline{B}$; A.1 implies that F needs to terminate after e_B (else R would choose e_B and the resulting payoff for F is strictly smaller than Π^*_{NO}); the incentive-compatibility constraint such that F continues iff $e = e_N$ is $\overline{N} > p_C - p_T \geq \underline{N}$ for all o_T; and the incentive-compatibility constraint ensuring that R chooses e_N is $p_C - p_T > \overline{B}$ for $o_T = \text{ø}$ or $o_T = N$ and $p_C - p_T > 0$ for $o_T = B$ or $o_T = B + N$.

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

$\overline{B} < \overline{N}$ *for* $o_T = \varnothing$ *and for* $o_T = N$

$\underline{B} < \overline{N}$ *for* $o_T = B$ *and for* $o_T = B+N$

In these cases, the maximization problem of F amounts to minimizing p_C under the above constraints, and we can bound the optimal p^*_C (if it exists):

$$p^*_C \geq \begin{cases} \max\{\overline{B}, \underline{N}\} & \text{for } o_T = \varnothing \text{ and for } o_T = N \\ \max\{\underline{B}, \underline{N}\} & \text{for } o_T = B \text{ and for } o_T = B+N \end{cases}$$

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

(iii) It remains to be shown that contracts inducing continuation, with $o_C = N$ but $o_T \neq N + B$ yield a payoff weakly smaller than Π^*_{NO} or $\hat{\Pi}_O$. Note first that $o_C = N$ implies that the participation constraint for R is not binding since R receives B. Also note that, as above, A.1 implies that F needs to terminate after e_B (else R would choose e_B and the resulting payoff for F is

strictly smaller than Π^*_{NO}). The incentive compatibility constraints ensuring that F continues iff e_N is $\overline{N} > p_C - p_T \geq \underline{N}$ and the incentive compatibilitv constraint ensuring that R chooses e_N is

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

The constraints imply the additional condition $\overline{B} - \underline{B} < \overline{N}$ for existence in the two cases $o_T = \varnothing$ and $o_T = N$.

The maximization problem amounts to minimizing p_C under the above constraints and yields:

$$p_C^* = \begin{cases} \max\{\overline{B} - \underline{B}, \underline{N}\} & \text{for } o_T = \varnothing \text{ or } o_T = N \\ \underline{N} & \text{for } o_T = B \end{cases}$$

and the resulting payoff $\Pi_O = \overline{N} - p_C^* - I$ is weakly 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 $\Pi_O > \hat{\Pi}_O$.

(2.) For the class of option contracts with $i = R$, contracts that (i) induce termination in equilibrium or (ii) induce continuation in equilibrium but with $o_C \neq N$ are ruled out the same way as for $i = F$: either the F's payoff is strictly negative, $\Pi_O = -p_C - I$, or R cannot be induced to exert e_N since R's payoff after e_B is weakly higher. Similarly, contracts that (iii) induce continuation in equilibrium, with $o_C = N$ but with $o_T \neq N + B$ will always induce R to choose e_B since R's payoff after continuation if choosing e_N is 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 no option contract with $i = R$ and payoff Π_O satisfying $\Pi_O > \Pi^*_{NO}$ and $\Pi_O > \hat{\Pi}_O$. **Q.E.D.**

Proof of Lemma 1′. To induce e_N, F needs to terminate after e_B and to continue after e_N; under any other termination rule (i.e., termination after both, only after e_N, or never) R would always choose effort e_B (assumption A.1) and obtain a weakly higher payoff.

Under the contractual provisions $i = F$, $o_C = N$, and $o_T = N + B$, F terminates after e_B iff $\underline{N} - p_C \leq \alpha\underline{N} + \varepsilon\overline{B} - p_T$ and continues after e_N iff $\overline{N} - p_C > \alpha\overline{N} + \varepsilon\underline{B} - p_T$. Solving these two inequalities for p_C - p_T yields (1′). Given F's conditional termination decisions, R receives payoff p_T after e_B and $\underline{B} + p_C$ after e_N. Hence, R chooses e_N if and only if $p_C - p_T > -\underline{B}$. This is implied by (1). Hence, prices (p_C, p_T) satisfying (1′) are necessary and sufficient to induce F to terminate iff R chooses e_B. **Q.E.D.**

Proof of Lemma 2′. 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*'s financial constraints. 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 if $p_T < -\Delta$. Therefore, setting $p_C = 0$ and picking any $p_T \in [0, -\Delta]$ is optimal. (c) Similarly, if $0 \geq \Gamma > \Delta$, the non-negativity constraint on p_C is binding for $p_T < -\Delta$, and setting $p_C = 0$ requires $-\Gamma < p_T \leq -\Delta$. **Q.E.D.**

Proof of Proposition 2′. We consider separately option contracts with $i = F$ and with $i = R$.

(1.) Among option contracts with $i=F$, we distinguish (i) contracts inducing termination in equilibrium, (ii) those inducing continuation in equilibrium but with $o_C \neq N$, (iii) those inducing continuation in equilibrium and with $o_C = N$ but with $o_T \neq N + B$.

(i) To show that *F*'s payoff Π_O from any option contract inducing termination in equilibrium is weakly smaller than Π^*_{NO} or strictly smaller than $\hat{\Pi}_O$, 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.4) $\Pi_O < 0 \leq \Pi^*_{NO}$.

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.4) $\Pi_O < \alpha N - I < \hat{\Pi}_O$.

(ii) In the set of contracts inducing continuation in equilibrium but not allocating (only) the narrow rights to *F*, we distinguish three 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 $\Pi_O < 0 \leq \Pi^*_{NO}$.

If $o_C = N + B$, then $\Pi_O = N + \varepsilon B - p_C - I$, where *R*'s participation constraint implies $p_C \geq \underline{B}$; A.1 implies that *F* needs to terminate after e_B (else *R* would choose e_B and the resulting payoff for *F* is strictly smaller than Π^*_{NO}); the incentive-compatibility constraints such that *F* continues iff $e = e_N$ are

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

and 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

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

In these cases, the maximization problem of *F* amounts to minimizing p_C under the above constraints, and we can bound the optimal p^*_C (if it exists):

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

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.

(iii) It remains to be shown that contracts inducing continuation, with $o_C = N$ but $o_T \neq N + B$ yield a payoff weakly smaller than Π_{NO}^* or strictly smaller than $\hat{\Pi}_O$. Note first that $o_C = N$ implies that the participation constraint for *R* is not binding since *R* receives *B*. Also note that, as above, A.1 implies that *F* needs to terminate after e_B (else *R* would choose e_B and the resulting payoff for *F* is strictly smaller than Π_{NO}^*). The incentive compatibility constraints ensuring that *F* continues iff e_N is

$$\left.\begin{array}{l}\overline{N}\\ \overline{N} - \varepsilon \underline{B}\\ (1-\alpha)\overline{N}\end{array}\right\} > p_C - p_T \geq \begin{cases}\underline{N} & for\ o_T = \varnothing\\ \underline{N} - \varepsilon \overline{B} & for\ o_T = B\\ (1-\alpha)\underline{N} & for\ o_T = N\end{cases}$$

and the incentive compatibility constraint ensuring that *R* chooses e_N is

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

The constraints imply additional conditions for existence in two cases:

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

The maximization problem amounts to minimizing p_C under the above constraints and yields:

$$p_C^* = \begin{cases}\max\{\overline{B} - \underline{B},\ \underline{N}\} & for\ o_T = \varnothing\\ \max\{\underline{N} - \varepsilon \overline{B}; 0\} & for\ o_T = B\\ \max\{\overline{B} - \underline{B},\ (1-\alpha)\underline{N}\} & for\ o_T = N\end{cases}$$

and the resulting payoff $\Pi_O = \overline{N} - p_C^* - I$ is strictly 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 $\Pi_O \geq \hat{\Pi}_O$.

(2) For the class of contracts with $i = R$, 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 $i = F$. 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.**

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

$$\overline{N} > p_C - p_T \geq \underline{N} \qquad \text{and} \qquad p_C - p_T > \overline{B} - \underline{B} \tag{1″}$$

Proof. Notice that the set of admitted values for $p_C - p_T$ described in (1‴) is non-empty since we are considering the case $\overline{N} + \underline{B} > \underline{N} + \overline{B}$.

The condition $p_C - p_T \geq \underline{N}$ guarantees that F chooses to terminate when $e = e_B$. The condition $\overline{N} > p_C - p_T$ guarantees that F chooses to continue when $e = e_N$. Finally, $p_C - p_T > \overline{B} - \underline{B}$ guarantees that R chooses e_N. **Q.E.D.**

Moreover such a contract can be implemented with the following prices:

Lemma 2‴. *In the set of option contracts* $(F, p_C, p_T, N, \varnothing)$ *that implement* e_N, *setting* $p_C = 0$ and $-\overline{N} < p_T \leq -\underline{N}$ *and* $p_T < -(\overline{B} - \underline{B})$ *maximizes* F*'s payoff.*

Proof. The prices implement e_N by Lemma 1‴. Since the equilibrium payoff of R under this contract is its reservation utility $\underline{B}$, the profit of F cannot be increased further without violating the participation constraint of R. **Q.E.D.**

Lemma 2‴ illustrates that there are several types of option contracts achieving the same maximum payoff for F as option contracts in $\hat{A}_O$.

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 after $t = 1$. As in Nöldeke and Schmidt (1995), we assume that, after R has exerted effort e in $t = 1$ but before $t = 2$, 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 $t = 2$, the parties can present any signed offer they received in court. The court observes whether F initiated termination or not and enforces 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, or
- 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* (i) 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 under the original contract, and (ii) make a renegotiation offer if their renegotiated equilibrium payoff in the continuation game is strictly larger than the original equilibrium payoff.

We apply the concept of subgame-perfect equilibrium. Given this renegotiation mechanism, we can specify when the contract derived in Lemma 2′ is renegotiation-proof.

Lemma 4′. *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.

(1) After effort choice e_N, the original contract allows for extraction of the full surplus $\overline{N} + \underline{B}$. 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.

(2) After 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, 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 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 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 after termination under the original contract.
2. *R*'s equilibrium 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. We can rule out offers that assign no rights or only broad rights to *F* since the resulting payoff for *F* would be smaller than the original equilibrium payoff (given *R*'s financial constraints).

(i) *Broad and narrow rights*. In order to accept *R*'s renegotiation offer and to choose continuation, *F* requires a continuation payoff $\underline{N} + \varepsilon\overline{B} - \tilde{p}_C$ 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 $\tilde{p}_C$ is $\tilde{p}_C \le (1-\alpha)\underline{N} + p_T$. 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 specifying $\delta_C = N + B$.

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

For $\Delta < 0$, we can find such a $\tilde{p}_C$ only if the original p_T was set equal to the upper bound $-\Delta$ (namely $\tilde{p}_C$=0). For all other p_T the upper bound on $\tilde{p}_C$, i.e. $(1-\alpha)\underline{N} - \varepsilon\overline{B} + p_T = \Delta + p_T$, is negative and, given the non-negativity constraint for prices, we cannot find a smaller $\tilde{p}_C$. Hence, by choosing $p_T < -\Delta$ (within the ranges specified in Lemma 2′), *F* prevents renegotiation, induces *R* to exert e_N, and obtains the resulting higher payoff.

For $\Delta \ge 0$, any $\tilde{p}_C \in [0, \Delta]$ 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 $\tilde{p}_C$, i.e., $\tilde{p}_C = \Delta$, 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 4′ 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 $\Delta \ge \overline{N} - \max\{\underline{N}, I\}$, where $\hat{\Pi}_O \le \Pi^*_{NO}$ (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 $0 \le \Delta < \overline{N} - \max\{\underline{N}, I\}$. 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 4′, we can summarize *F*'s contractual choice as follows.

Proposition 3. *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* $0 \le \Delta < \overline{N} - \tilde{\Delta} - (\overline{B} - \underline{B})$, *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* $\widetilde{\Pi}_O = \overline{N} - (\overline{B} - \underline{B}) - \Delta - I$. *If* $0 \le \overline{N} - \widetilde{\Delta} - (\overline{B} - \underline{B}) < \Delta$, *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 4′). 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 $\Delta \ge \overline{N} - \max\{\underline{N}, I\}$, any contract in A^*_{NO} maximizes *F*'s payoff (Lemma 3′), and *F* obtains payoff $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$.

For $0 \le \Delta < \overline{N} - \max\{\underline{N}, I\}$, $\hat{\Pi}_O > \Pi^*_{NO}$ (Lemma 3′) but no option contract in $\hat{A}_O$ is renegotiation-proof (Lemma 4′). 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 $\widetilde{p}_C$ such that, conditional on *R* having chosen e_B, *F* accepts the renegotiation offer (F, $\widetilde{p}_C$, p_T, N, $N + B$) and chooses continuation, namely any non-negative $\widetilde{p}_C$ for which $\alpha\underline{N} + \varepsilon\overline{B} - p_T \le \underline{N} - \widetilde{p}_C$, i. e. $\widetilde{p}_C \in [0, \Delta + p_T]$. Whether *R* chooses e_B and renegotiation or, instead, 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 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, is $\underline{N} - \widetilde{p}_C - I$, which is weakly smaller than $\underline{N} - I$ and hence than Π^*_{NO}. 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 $p_C \ge \overline{B} - \underline{B} + \Delta + p_T$. *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 $0 \le \Delta < \overline{N} - \max\{\alpha\overline{N} + \varepsilon\underline{B}, \underline{N}, I\} - (\overline{B} - \underline{B})$, F chooses option contract (*F*, $\overline{B} - \underline{B} + \Delta$, 0, *N*, *N* + *B*) and obtains payoff $\tilde{\Pi}_O = \overline{N} - (\overline{B} - \underline{B}) - \Delta - I$. **Q.E.D.**

Proposition 3 shows that renegotiation may reduce the range over which an option contract with termination rights and reversion of intellectual property is optimal, namely if $\Delta < \overline{N} - \tilde{\Delta} - (\overline{B} - \underline{B})$. We illustrate the difference between the case with commitment (no renegotiation) and the case without commitment (renegotiation possible) in Figure 4. As the graphs show, the basic finding, however, remains unaltered: 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 firm correspond to a lower 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 profitable.

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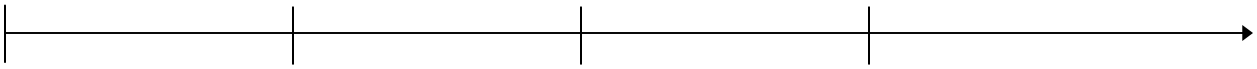
Figure 1. Timeline



t = 0
Contract

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

t = 2
– (Future) Realization of *N* and *B* become observable to *F*
– Termination?
– Payments p_C or p_T

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

t = 3
Marketing and Sales Phase
– Realization of *N* and *B*

Figure 2. Table of Payoffs

(a) Simplified Set-up: No Outside Benefits for F ($\alpha = \varepsilon = 0$)

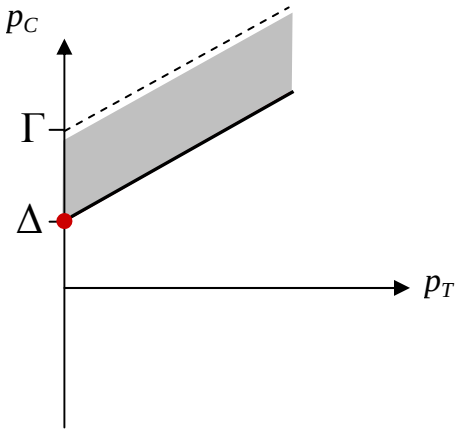
	F's rights	F's payoff	R's payoff
Continuation	$o_C = \varnothing$	$-p_C - I$	$B + p_C$
	$o_C = N$	$N - p_C - I$	$B + p_C$
	$o_C = B$	$-p_C - I$	p_C
	$o_C = N + B$	$N - p_C - I$	p_C
Termination	$o_T = \varnothing$	$-p_T - I$	$B + p_T$
	$o_T = N$	$-p_T - I$	$B + p_T$
	$o_T = B$	$-p_T - I$	p_T
	$o_T = N + B$	$-p_T - I$	p_T

(b) Extended set-up: Outside Benefits for F ($0 < \alpha < 1$, $0 < \varepsilon < 0$)

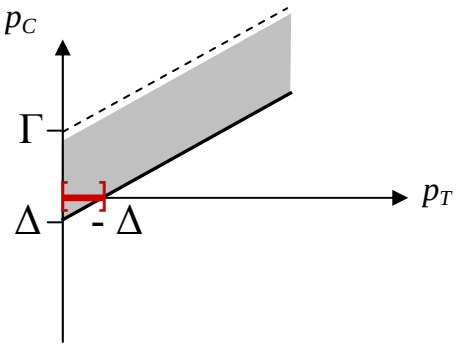
	F's rights	F's payoff	R's payoff
Continuation	$o_C = \varnothing$	$-p_C - I$	$B + p_C$
	$o_C = N$	$N - p_C - I$	$B + p_C$
	$o_C = B$	$\varepsilon B - p_C - I$	p_C
	$o_C = N + B$	$N + \varepsilon B - p_C - I$	p_C
Termination	$o_T = \varnothing$	$-p_T - I$	$B + p_T$
	$o_T = N$	$\alpha N - p_T - I$	$B +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

Figure 3. Illustration of Lemmas 2 and 2″

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



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



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

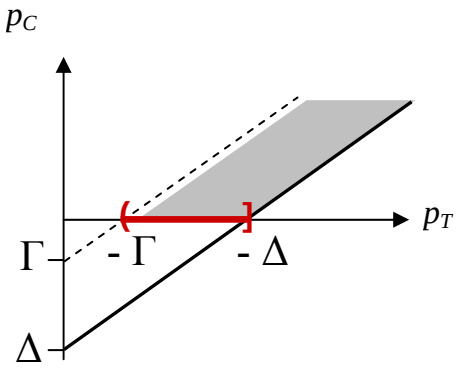
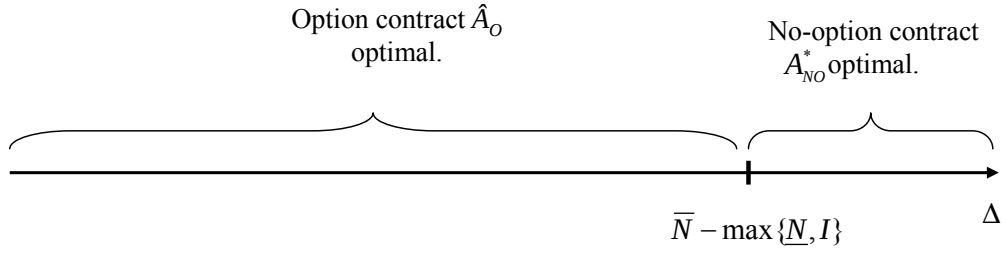


Figure 4. Ranges of Optimal Contracts

(a) Parties commit not to renegotiate



(b) Parties cannot commit not to renegotiate

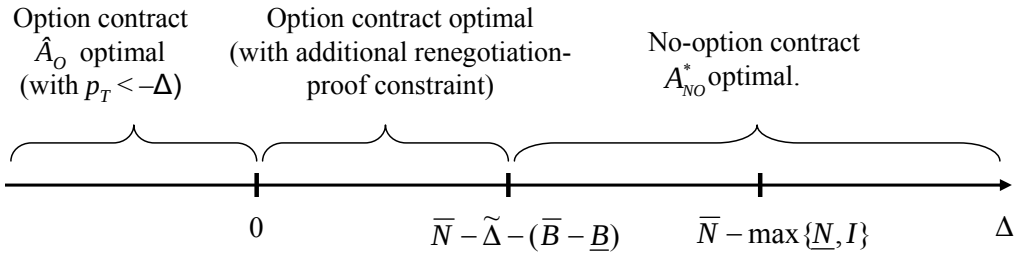


Table 1. Sample construction

Sample Construction, starting from ReCap universe	Observations
Agreements analyzed by ReCap, entered into through end of 2001, as of January 2003:	1108
Less agreements involving universities, non-profits, and hospitals (311):	797
Less "marketing only" agreements (127):	670
Less agreements involving renegotiations of existing agreements (62):	608
Less agreements involving three or more parties (14):	594
Less non-arm's length agreements (10):	584
Less duplicated agreements (3):	581
Less agreements no longer present in Recap as of July 2006 (1):	580

Additional data gathering steps:	Observations
ReCap disease/keyword data available	580
Financing category determined from contract analysis	580
Patent data available*	580
Carter-Manaster rank data available	526
Financial Health Index data available	551
Data on previous alliances between two firms available	551
All above data available	483

*5 agreements with insufficient keywords coded as 0

Table 2. Summary statistics

Variable Name	# Obs.	Mean	Stan. Dev.	Min.	Max.	Median
Date	580	1995.85	3.73	1980.04	2001.71	1996.88
Carter-Manaster rank of lead bank in research firm's IPO	526	7.71	1.99	1	9	8.75
No specifiable lead product	580	0.37	0.48	0	1	0
Unknown if specifiable lead product	580	0.11	0.31	0	1	0
Agreement involves diagnostic product	580	0.13	0.34	0	1	0
Agreement involves veterinary product	580	0.05	0.23	0	1	0
Agreement between two biotechnology firms	580	0.17	0.37	0	1	0
Research firm's revenue in prior fiscal year	558	11.47	37.21	0	523.22	0.71
Research firm's cash flow in prior fiscal year	535	2.57	176.14	-331	2398.26	-6.66
Research firm's net income prior fiscal year	558	1.38	189.12	-351.95	2474.34	-7.48
Research firm's cash holdings in prior fiscal year	551	46.04	134.69	0	1452.36	12.53
Financial Health Index	551	0.62	0.27	0	1	0.67
Patent awards to the research firm at the time of the research agreement signing	580	8.66	20.12	0	178	1
Number of previous research agreements between financing and research firms	551	0.11	0.40	0	3	0
Total number of research agreements signed by research firm in previous 3 years	580	6.39	6.78	0	45	4
Total number of research agreements signed by research firm in previous 3 years with any technology match	580	4.77	6.56	0	53	3
Total number of research agreements signed by research firm in previous 3 years with exact technology match	580	1.95	2.92	0	18	1
Any unilateral termination rights?	580	0.97		0	1	1
Any termination rights for financing firm?	580	0.96		0	1	1
Any unconditional termination rights for financing firm?	580	0.39		0	1	0
Any unconditional termination rights for financing firm and broad intellectual property rights?	580	0.11		0	1	0

Table 3. Cross-tabulations of contract characteristics

Panel A: Simple Comparisons

Mean number of unconditional termination rights assigned to the financing firm
(combined with broad intellectual property rights)

If no specifiable lead product	Otherwise	t-Statistic, Test of Difference	p-Value
0.21	0.11	2.66	0.008
If research agreement involves diagnostic technologies	Otherwise	t-Statistic, Test of Difference	p-Value
0.05	0.16	-2.02	0.044
If research agreement involves veterinary technologiess	Otherwise	t-Statistic, Test of Difference	p-Value
0.03	0.16	-1.49	0.136
If research agreement between two biotechnology firms	Otherwise	t-Statistic, Test of Difference	p-Value
0.25	0.13	2.34	0.020
If research firm has above median net income	Otherwise	t-Statistic, Test of Difference	p-Value
0.14	0.15	-0.10	0.923
If research firm has high-status underwriter	Otherwise	t-Statistic, Test of Difference	p-Value
0.20	0.13	1.55	0.114

Panel B: Cross-Tabulations

Mean number of unconditional termination rights assigned to financing firm
(combined with broad intellectual propperty rights)

Research firm with below median net income:

If no specifiable lead product	Otherwise	t-Statistic, Test of Difference	p-Value
0.25	0.10	2.47	0.014

Research firms with above median net income:

If no specifiable lead product	Otherwise	t-Statistic, Test of Difference	p-Value
0.18	0.12	1.07	0.286

Research firms with low-ranking underwriter:

If no specifiable lead product	Otherwise	t-Statistic, Test of Difference	p-Value
0.18	0.11	1.29	0.197

Research firms with high-ranking underwriter:

If no specifiable lead product	Otherwise	t-Statistic, Test of Difference	p-Value
0.29	0.12	2.24	0.026

Table 4. Regression analysis of contract design

	Ordered logit	Ordered logit	OLS	OLS with year fixed effects	OLS with year and firm fixed effects
	(1)	(2)	(3)	(4)	(5)
Date	0.012	0.032	0.005		
	[0.039]	[0.043]	[0.006]		
No specifiable lead product	0.678	0.680	0.126	0.140	0.139
	[0.292]**	[0.315]**	[0.047]***	[0.049]***	[0.050]***
Unknown if specifiable lead product	-0.11	0.031	0.002	-0.011	0.014
	[0.516]	[0.527]	[0.070]	[0.073]	[0.075]
Agreement involves diagnostic product	-0.889	-0.794	-0.096	-0.103	-0.097
	[0.540]	[0.545]	[0.061]	[0.064]	[0.065]
Agreement involves veterinary product	-1.413	-1.336	-0.12	-0.123	-0.107
	[1.034]	[1.037]	[0.090]	[0.095]	[0.096]
Carter-Manaster rank of lead underwriter of research firm's IPO	0.003	0.032	0.01	0.009	0.009
	[0.070]	[0.077]	[0.011]	[0.011]	[0.011]
Number of patents of research firm		0.006	0.001	0.001	0.001
		[0.007]	[0.001]	[0.001]	[0.001]
Financial Health Index		0.732	0.075	0.119	0.119
		[0.557]	[0.077]	[0.083]	[0.084]
Number of previous research agreements		-0.016	-0.005	-0.004	-0.019
between financing and research firms		[0.352]	[0.051]	[0.053]	[0.054]
Constant			-10.739	0.027	-0.12
			[11.783]	[0.490]	[0.513]
Year Fixed Effects				X	X
Financing Firm Fixed Effects					X
Number of observations	526	483	483	483	483
R-squared			0.04	0.07	0.09

Notes
Dependent variable is the number of unconditional termination rights assigned to financing firm (combined with broad intellectual property rights).
Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5. Regression analysis of contract design: alternative proxies and additional controls

	Alternative proxy for incentive conflicts (multi-tasking): other research agreements		Sample excludes financing firms with related patents		Sample restricted to agreements not defined as joint ventures by ReCap	Sample excludes agreements where text indicates that financing firm is also involved in research	Sample eliminates agreements on veterinary and diagnostic products	With fixed effects for disease categories
			Broad definition	Narrow definition				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No specifiable lead product		0.124	0.141	0.103	0.143	0.192	0.172	0.163
		[0.051]**	[0.085]*	[0.049]**	[0.058]**	[0.059]***	[0.059]***	[0.052]***
Unknown if specifiable lead product		0.012	0.009	0.002	0.011	0.014	0.038	0.032
		[0.075]	[0.115]	[0.073]	[0.084]	[0.080]	[0.093]	[0.094]
Agreement involves diagnostic product	-0.091	-0.095	-0.088	-0.086	-0.077	-0.070		-0.091
	[0.066]	[0.065]	[0.098]	[0.063]	[0.072]	[0.073]		[0.067]
Agreement involves veterinary product	-0.105	-0.110	-0.185	-0.080	-0.112	-0.081		-0.099
	[0.096]	[0.096]	[0.155]	[0.094]	[0.100]	[0.111]		[0.097]
Carter-Manaster rank of lead underwriter of research firm's IPO	0.014	0.009	0.013	0.011	0.009	0.016	0.008	0.008
	[0.011]	[0.011]	[0.017]	[0.011]	[0.013]	[0.013]	[0.013]	[0.012]
Number of patents of research firm	0.000	0.000	0.000	0.000	0.002	0.002	0.001	0.001
	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Financial Health Index	0.082	0.091	0.104	0.048	0.139	0.155	0.139	0.118
	[0.086]	[0.086]	[0.131]	[0.081]	[0.092]	[0.091]*	[0.099]	[0.085]
Number of previous research agreements	-0.040	-0.029	0.031	0.003	0.020	0.019	-0.021	-0.018
between financing and research firms	[0.055]	[0.055]	[0.102]	[0.052]	[0.060]	[0.061]	[0.066]	[0.055]
Total number of alliances signed by research firm in	0.008	0.006						
3 years before alliance	[0.004]**	[0.004]						
Constant	-0.164	-0.103	-0.146	-0.107	0.059	-0.079	-0.231	-0.120
	[0.515]	[0.513]	[0.517]	[0.488]	[0.497]	[0.503]	[0.526]	[0.520]
Year Fixed Effects	X	X	X	X	X	X	X	X
Financing Firm Fixed Effects	X	X	X	X	X	X	X	X
Disease Category Fixed Effects								X
Number of observations	483	483	235	458	371	360	394	483
R-squared	0.08	0.10	0.20	0.10	0.09	0.13	0.09	0.11

Notes

Dependent variable is the number of unconditional termination rights assigned to financing firm (combined with broad intellectual property rights).

The broad definition in regression (3) excludes any research agreement where the financing firm had a patent or pending patent application with any of the alliance keywords at the time of the agreement signing.

The narrow definition in regression (4) excludes any research agreements where the financing firm had a patent or pending patent application with all of the alliance keywords at the time of the agreement signing.

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6. Regression analysis of contract design: separating research firms with high and low net income

	Low Net Income (1)	High Net Income (2)	Low Net Income (3)	High Net Income (4)	Pooled Regression (5)
Date	0.003	0.011			
	[0.011]	[0.008]			
No specifiable lead product	0.171	0.07	0.200	0.092	
	[0.070]**	[0.068]	[0.076]***	[0.074]	
Unknown if specifiable lead product	0.029	-0.036	0.040	-0.038	
	[0.104]	[0.097]	[0.114]	[0.110]	
Agreement involves diagnostic product	-0.073	-0.084	-0.073	-0.074	-0.086
	[0.090]	[0.087]	[0.097]	[0.103]	[0.066]
Agreement involves veterinary product	-0.106	-0.126	-0.096	-0.146	-0.104
	[0.132]	[0.126]	[0.147]	[0.148]	[0.096]
Carter-Manaster Rank of lead underwriter of research firm's IPO	0.018	0.007	0.017	0.005	0.011
	[0.016]	[0.015]	[0.017]	[0.017]	[0.012]
Number of patents of research firm	0.001	0.004	0.001	0.003	0.001
	[0.001]	[0.004]	[0.001]	[0.004]	[0.001]
Financial Health Index	0.035	0.08	0.099	0.098	0.11
	[0.126]	[0.101]	[0.141]	[0.116]	[0.084]
Number of previous research agreements	-0.03	0.021	-0.078	0.055	-0.021
between financing and research firms	[0.067]	[0.089]	[0.073]	[0.101]	[0.054]
Constant	-6.869	-22.205	0.125	0.101	
	[22.562]	[15.196]	[0.589]	[0.561]	
Below median net income dummy					-0.234
					[0.521]
Above median net income dummy					-0.139
					[0.514]
(Below-Median Dummy)*(No specifiable lead product)					0.180
					[0.069]***
(Above-Median Dummmy)*(No specifiable lead product)					0.082
					[0.071]
(Below-Median Dummy)*(Unknown if specifiable lead product)					0.046
					[0.103]
(Above-Median Dummmy)*(Unknown if specifiable lead product)					-0.033
					[0.105]
Year Fixed Effects			X	X	X
Financing Firm Fixed Effects			X	X	X
Number of observations	249	234	249	234	483
R-squared	0.05	0.04	0.13	0.14	0.19

Notes
Dependent variable is the number of unconditional termination rights assigned to financing firm (combined with broad intellectual property rights).
Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7. Regression analysis of contract design: separating research firms with high and low reputation underwriters

	High Rank Underwriter (1)	Low Rank Underwriter (2)	High Rank Underwriter (3)	Low Rank Underwriter (4)	Pooled Regression (5)
Date	0.007	0.004			
	[0.012]	[0.006]			
No specifiable lead product	0.198	0.07	0.189	0.093	
	[0.094]**	[0.054]	[0.105]*	[0.057]	
Unknown if specifiable lead product	0.046	0.007	0.007	0.033	
	[0.139]	[0.079]	[0.156]	[0.085]	
Agreement involves diagnostic product	-0.21	-0.05	-0.217	-0.071	-0.099
	[0.122]*	[0.066]	[0.148]	[0.070]	[0.066]
Agreement involves veterinary product	-0.19	-0.055	-0.201	-0.015	-0.102
	[0.158]	[0.106]	[0.186]	[0.114]	[0.096]
Carter-Manaster Rank of lead underwriter of research firm's IPO	-0.874	0.005	-1.329	0.002	0.004
	[0.625]	[0.011]	[0.748]*	[0.011]	[0.013]
Number of patents of research firm	0.001	0.002	-0.001	0.001	0.001
	[0.002]	[0.002]	[0.002]	[0.002]	[0.001]
Financial Health Index	0.192	0.03	0.262	0.097	0.12
	[0.153]	[0.084]	[0.180]	[0.092]	[0.084]
Number of previous research agreements	-0.032	0.02	-0.057	0.036	-0.017
between financing and research firms	[0.105]	[0.054]	[0.118]	[0.063]	[0.054]
Constant	-5.759	-7.938	11.856	-0.148	
	[23.834]	[12.746]	[6.751]*	[0.314]	
High-Rank Dummy					-0.079
					[0.517]
Low-Rank Dummmy					-0.086
					[0.515]
(High-Rank Dummy)*(No specifiable lead product)					0.193
					[0.077]**
(High-Rank Dummmy)*(Unknown if specifiable lead product)					0.004
					[0.112]
(Low-Rank Dummmy)*(No specifiable lead product)					0.08
					[0.066]
(Low-Rank Dummmy)*(Unknown if specifiable lead product)					0.028
					[0.099]
Year Fixed Effects			X	X	X
Financing Firm Fixed Effects			X	X	X
Number of observations	189	294	189	294	483
R-squared	0.07	0.02	0.17	0.12	0.19

Notes
Dependent variable is the number of unconditional termination rights assigned to financing firm (combined with broad intellectual property rights).
Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 8. Regression analysis of contract design: different types of termination rights

	Termination Rights of Financing Firm (without Requiring Product Right Reversion)				Conditional Termination and Property Rights	
	Ordered Logit	Ordered Logit	OLS	OLS with year and firm fixed effects	OLS	OLS with year and firm fixed effects
	(1)	(2)	(3)	(4)	(5)	(6)
Date	-0.026	-0.023	-0.003		0.005	
	[0.023]	[0.025]	[0.010]		[0.003]	
No specifiable lead product	-0.28	-0.273	-0.104	-0.092	0.024	0.027
	[0.195]	[0.209]	[0.080]	[0.082]	[0.028]	[0.028]
Unknown if specifiable lead product	-0.248	-0.185	-0.001	-0.054	-0.026	-0.013
	[0.304]	[0.318]	[0.118]	[0.124]	[0.040]	[0.043]
Agreement involves diagnostic product	-0.878	-0.887	-0.287	-0.274	-0.043	-0.052
	[0.290]***	[0.296]***	[0.103]***	[0.108]**	[0.035]	[0.037]
Agreement involves veterinary product	-0.48	-0.406	-0.156	-0.129	0.029	0.024
	[0.411]	[0.418]	[0.152]	[0.158]	[0.052]	[0.055]
Carter-Manaster Rank of lead underwriter of research firm's IPO	0.003	0.004	-0.013	-0.009	0.006	0.01
	[0.046]	[0.048]	[0.018]	[0.019]	[0.006]	[0.007]
Number of patents of research firm		-0.003	0	-0.001	-0.001	-0.001
		[0.005]	[0.002]	[0.002]	[0.001]	[0.001]
Financial Health Index		0.873	0.264	0.235	-0.103	-0.08
		[0.346]**	[0.131]**	[0.138]*	[0.045]**	[0.048]*
Number of previous research agreements		0.041	0.002	-0.085	0.034	0.032
between financing and research firms		[0.210]	[0.086]	[0.090]	[0.030]	[0.031]
Constant			6.228	1.088	-8.996	-0.026
			[19.888]	[0.850]	[6.829]	[0.294]
Year Fixed Effects				X		X
Financing Company Fixed Effects (dummies for major pharmaceutical companies)				X		X
Observations	526	483	483	483	483	483
R-squared			0.03	0.12	0.03	0.1

Notes
Dependent variable in regressions (1) through (4) is the total number of unconditional termination rights assigned to financing firm.
Dependent variable in regressions (5) and (6) is the number of conditional termination rights assigned to financing firm (combined with broad intellectual property rights).
Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%