

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

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

III. Model

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

For simplicity, we focus on the case¹¹

$$\underline{B} > \varepsilon \bar{B}. \quad (\text{A.3})$$

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

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

contract under the assumption that R 's research is observable¹² but not verifiable. We then introduce option rights and analyze whether they allow the financing company to extract a greater share of the surplus. In particular, we consider the option to terminate the research collaboration after F has observed R 's effort and the research output of the initial research phase. Note that this implies that collaboration in the development phase is contractible and that the courts can observe termination, i.e., which of the parties (if any) decided not to continue the collaboration after the research phase. We assume

$$F \text{ terminates if indifferent between termination and continuation.} \quad (\text{A.4})$$

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

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

- (i) the initial payment I by the financing company F at $t = 1$,
- (ii) the conditions for termination (if any) at $t = 2$,
- (iii) the payments from F to R at $t = 2$,
- (iv) the rights F obtains from R , which may be narrow or broad.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

It remains to be shown that R chooses e_N , given F 's conditional termination decisions. R receives payoff p_T for effort e_B and $\underline{B} + p_C$ for effort e_N . Hence, R chooses e_N if and only if $p_C - p_T > -\underline{B}$.

This is implied by (1) since $p_C - p_T \geq (1-\alpha)\underline{N} - \varepsilon\bar{B} > -\varepsilon\bar{B} > -\underline{B}$ with assumption A.3. **Q.E.D.**

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

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

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

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

maximizes F 's payoff.

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

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

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

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

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

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

Q.E.D.

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

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

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

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

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

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

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

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

$$\Pi_o \leq \Pi_{NO}^* \quad \vee \quad \Pi_o < \hat{\Pi}_o.$$

Proof. See Appendix B.

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

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

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

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

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

We thus reach three main predictions:

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

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

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

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