Online Appendix

Online-Appendix A: Case Evidence

Cross-subsidization. In our interviews with industry executives and lawyers, cross-subsidization was highlighted as a major concern in the negotiations leading to research agreements and in subsequent disputes. A lawyer frequently involved in these negotiations argued that, while formal dispute-resolution mechanisms partially address the problem, 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.

One illustration of the difficulty of contracting in biotechnology alliances is a 1993 case, in which 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).

Academic Interests. The concept that incentives of researchers may differ between firms has been well-discussed. Stern (2004) points out that scientists are willing to accept lower wages in return for undertaking more science-oriented research. To cite a characteristic example of the kinds of conflicts that are discussed in the practitioner-oriented literature, 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.

ALZA case. The research collaboration between drug delivery firm ALZA and Swiss pharmaceutical manufacturer Ciba-Geigy illustrates both the cross-subsidization and publication issues.[1] 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 collabora-

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

tions that ALZA representatives kept seeking to permission 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 concerned 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 its 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.

Online-Appendix B: 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 $\underline{N} + \varepsilon\overline{B} - \widetilde{p}_C$ that is weakly higher than the continuation payoff after termination under the original contract, $\alpha\underline{N} + \varepsilon\overline{B} - p_T$. The resulting upper bound of $\widetilde{p}_C$ is $\widetilde{p}_C \le (1-\alpha)\underline{N} + p_T$. Thus, *R* can at most ensure a payoff of $(1-\alpha)\underline{N} + p_T$ instead of $\overline{B} + p_C$ under the original contract. It is easy to check that, for all three subcases specified in Lemma 2′, *R*'s continuation payoff under the original contract is strictly higher. Hence, *R* will not choose e_B and then make a renegotiation offer specifying $\tilde{o}_C = N + B$.

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

For $\Delta < 0$, we can find such a $\widetilde{p}_C$ only if the original p_T was set equal to the upper bound $-\Delta$ (namely $\widetilde{p}_C = 0$). For all other p_T the upper bound on $\widetilde{p}_C$, 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 $\widetilde{p}_C$. 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 $\widetilde{p}_C \in [0, \Delta]$ satisfies the above condition and the non-negativity constraint. Conditional on having chosen e_B, *R* will thus make a renegotiation offer, proposing the highest possible $\widetilde{p}_C$, i.e., $\widetilde{p}_C = \Delta$, and receive $\overline{B} + \Delta$. Moreover, *R* prefers choosing e_B and renegotiating to choosing e_N, since $\overline{B} + \Delta > \underline{B} + \Delta$. **Q.E.D.**

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

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

Proof. For $\Delta < 0$, any contract in $\hat{A}_O$ maximizes *F*'s payoff under the assumption of no renegotiation (Lemma 3′). The subset of contracts with $p_T < -\Delta$ are renegotiation-proof (Lemma 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 $\Delta \geq \overline{N} - \max\{\underline{N}, I\}$, any contract in A^*_{NO} maximizes *F*'s payoff (Lemma 3′), and *F* obtains payoff $\Pi^*_{NO} = \max\{\underline{N} - I, 0\}$.

For $0 \leq \Delta < \overline{N} - \max\{\underline{N}, I\}$, $\hat{\Pi}_O > \Pi^*_{NO}$ (Lemma 3′) but no option contract in $\hat{A}_O$ is renegotiation-proof (Lemma 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 $\tilde{p}_C$ such that, conditional on *R* having chosen e_B, *F* accepts the renegotiation offer (F, $\tilde{p}_C$, p_T, N, $N + B$) and chooses continuation, namely any non-negative $\tilde{p}_C$ for which $\alpha\underline{N} + \varepsilon\overline{B} - p_T \leq \underline{N} - \tilde{p}_C$, i. e. $\tilde{p}_C \in [0, \Delta + p_T]$. 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 $p_C < \overline{B} - \underline{B} + \Delta + p_T$.

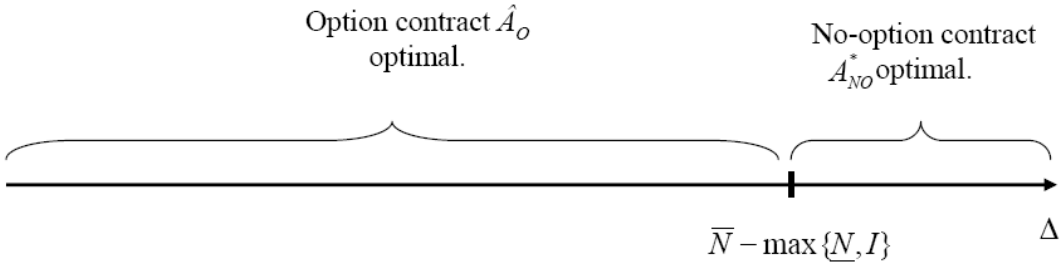
Consider now the first case (contracts that <u>are not</u> renegotiation-proof), i. e., option contracts (F, p_C, p_T, N, $N + B$) satisfying (1′) and $p_C < \overline{B} - \underline{B} + \Delta + p_T$. *F*'s payoff from implementing such a contract, after renegotiation, is $\underline{N} - \widetilde{p}_C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

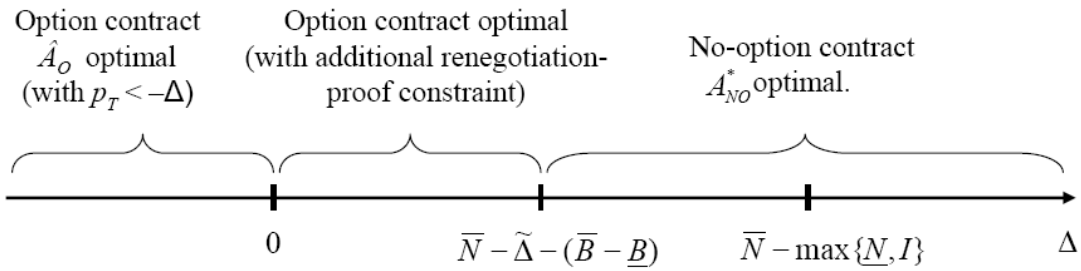
Proposition 3 shows that renegotiation may reduce the range over which an option contract with termination rights and reversion of intellectual property is optimal, namely if $\Delta < \overline{N} - \widetilde{\Delta} - (\overline{B} - \underline{B})$. We illustrate the difference between the case with commitment (no renegotiation) and the case without commitment (renegotiation possible) in Figure B1. As the graphs show, the basic finding 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.

Figure B1. Ranges of Optimal Contracts

(a) Parties commit not to renegotiate



(b) Parties cannot commit not to renegotiate



Online-Appendix C: Contract Excerpts

We provide excerpts from the "Field of Use" section or the preamble of the contract (as specified by ReCap), which define the scope of the collaboration.

The first two excerpts are from agreements with a pre-specified lead product candidate:

- *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.)

The following two excerpts are from agreements without a pre-specified lead product candidate:

- *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.)