9-2021

Turning the tables in research and development licensing contracts

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Research and development (R&D) collaborations between an innovator and her partner are often undertaken when neither party can bring the product to market individually, which precludes value creation without a joint effort. Yet R&D's uncertain nature complicates the monitoring of effort, and the resulting moral hazard reduces a collaboration's value. Either party can avoid this outcome by acquiring the capability that is missing and then taking sole ownership of the project. That approach involves two types of risks: one related to whether the other party's capability will be acquired, and one to how well it will be implemented (if acquired). We find that the extent of these two risks determines the optimality of delaying contracting or of signing contracts with buyout and buyback options, a baseball arbitration clause, or a novel reciprocal option. Baseball arbitration and reciprocal option clauses are unique in two ways. First, unlike typical options with pre-determined strike prices, they allow either party to determine the buyout price at the time of their offer. Second, they allow the offer's recipient to "turn the tables" on the other party. Although baseball arbitration and reciprocal option contracts both address inefficient joint development and product allocation, they exhibit their own inefficiencies that stem from the two parties' strategic behavior. The best choice of contract is determined by trade-offs between these inefficiencies. Our model explores the similarities between the baseball arbitration and reciprocal option clauses, and we propose a modification to the reciprocal option contract that would increase its profitability.

Key words: Research & Development; Innovation; Contract Design; Asymmetric Information; Arbitration
History: This version October 15, 2020

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1. Introduction

Global biopharmaceutical sales surpassed \$1 trillion in 2014; Pfizer's sales alone accounted for nearly \$50 billion (Statista 2015). Because most drugs lose much of their economic allure once patents expire and competition from generics brings prices down by as much as 90%, it is crucial for biopharmaceutical firms to replenish their product pipelines with new candidates (Aitken 2016).

Recent trends show that more than half of all newly approved drugs involve partnerships (Czerepak and Ryser 2008) and that partnered drugs are more likely to succeed (Markou et al. 2018). It follows that partnerships—which allow for the realization of synergies from complementary capabilities (Doz and Hamel 1998, Bhaskaran and Krishnan 2009, Crama et al. 2017) or the sharing of risk (Crama et al. 2008, Dechenaux et al. 2009, Bhattacharya et al. 2015) and alleviate cash constraints (Lerner and Merges 1998)—play a critical role in the vitality of the biopharmaceutical industry. Another recent trend is that partnerships are increasingly being formed at earlier stages in the research and development (R&D) cycle (Garcia 2008).

There are two sets of concerns related to partnerships that start at early stages of development. First, they involve higher market and regulatory risks, which the parties aim to reduce through their efforts. Moral hazard issues surface because the value created through the parties' efforts is shared. Second, early-stage alliances involve longer time frames that often exceed a decade (Figueiredo et al. 2015). Over such long time horizons, firms' capabilities are dynamic in the sense that firms make conscious efforts to acquire new capabilities by widening their resource base (Teece et al. 1997). The acquisition of a partner's complementary capability makes a company less dependent on the partner (Inkpen and Currall 2004), but it does not guarantee successful implementation of that capability (Ranft and Lord 2002). Furthermore, whereas a firm's acquisition of a new capability may be observable to others (as in the case, e.g., of hiring key personnel, undertaking a merger, or establishing new divisions), just how well that capability is implemented is an internal matter and private information.

The first set of concerns has been modeled extensively by the literature on new product development and technology licensing. We therefore start with a standard model of value creation efforts, capturing moral hazard, and show how the results of those efforts can be mapped to more general conditions of value. We place more emphasis on the second set of concerns. In particular, we explicitly model the efforts of each party to acquire the other's distinctive capability, the uncertainty of implementing an acquired capability, and the resulting asymmetric information structure—while also accounting for the moral hazard due to value creation efforts.

To maintain a consistent terminology throughout the paper, we refer to the stakeholders as follows. The party that owns the candidate product's intellectual property (IP) rights before a partnership agreement is the *innovator* (she), and the other party to the agreement is the *partner* (he). These two parties engage in an early-stage partnership agreement. Their distinct and complementary capabilities make development of the candidate product possible. Yet partnerships also involve various costs due to agency issues, such as moral hazard (Bhattacharya et al. 2015, Crama et al. 2017) and difficulties in coordination (Gulati and Singh 1998). Once one party's capability is acquired by the other party, the latter may benefit from avoiding the agency and coordination costs inherent to joint development by executing the project on its own.

Various contractual mechanisms enable either party to take the product in-house. We shall consider contracts with (i) buyout–buyback options, (ii) a baseball arbitration clause, and (iii) an innovative reciprocal option. The effectiveness of these contracts will be analyzed from the innovator's perspective. As a benchmark, we also model the innovator's choice to delay contracting until discovering whether she can acquire and how well she can implement her missing capability.

Options typically stipulate a strike price at which a party can exercise them (Dixit and Pindyck 1994). A buyout (resp. buyback) option allows the partner (resp. innovator) to buy out the innovator (resp. partner) at that pre-specified strike price. When the option is exercised, the party that was bought out is no longer involved in the project and so the product can be developed without incurring agency costs. A dual buyout–buyback option combines these two options in a single contract that allows either party to exercise the option in the event it acquires the other's capability.

When an option and its associated strike price are not specified in the contract, each party can still make an offer to buy out the other. However, the lack of an explicitly stated strike price may lead to a dispute about the offered price and about who should take ownership of the project. Such disputes are often resolved through arbitration, a process whereby a final and binding decision is made by an impartial arbitrator with legal and industry expertise (WIPOSurvey 2013). Indeed, the number of pharmaceutical disputes handled by the American Arbitration Association has been steadily increasing, and this industry is the sixth-largest contributor to the London Court of International Arbitration's caseload (Parker and Reeves 2018). We focus on baseball arbitration,[1] where the arbitrator reviews a proposal and counterproposal by two parties and decides which of the two shall prevail. We found baseball arbitration to be common in biopharmaceutical agreements, but its novelty in the operations literature motivated us to provide several examples in the eCompanion.

A reciprocal option likewise allows either party to buy out the other but differs from common buyout and buyback options in two important ways. First, like baseball arbitration, reciprocal options do not specify a strike price; instead, the "offeror" (the party making the offer) determines the strike price at the time of its offer. Second, such options allow the "offeree" (the party receiving the offer) to reciprocate and buy out the offeror at the offeror's strike price. Before describing the conditions under which these respective contracts are optimal, we next give examples of each: buyback option, baseball arbitration, and reciprocal option.

An agreement between Biohaven Pharmaceutical Corp. and Royalty Pharma, signed in 2018, included a buyback option for Biohaven that could be exercised at a pre-determined strike price.

[1] So called because of its similarity with how baseball players' salary disputes are resolved. In the 2019 Major League Baseball season, for example, Nolan Arenado (third baseman for the Colorado Rockies) filed for arbitration while proposing a salary of $30 million; the Rockies proposed $24 million (Perrotto 2019).

The agreement stated that Biohaven could exercise its option "for a purchase price of One Hundred Fifty-Five Million Dollars ($155,000,000) in cash (the 'Buy-Back Price')."

An agreement between Pfenex and Jazz Pharmaceuticals, entered in 2017, specified that disputes may be resolved through baseball arbitration "conducted by one arbitrator who shall be reasonably acceptable to the Parties ... [with] educational training and industry experience sufficient to demonstrate a reasonable level of scientific, financial, medical and industry knowledge relevant to the Dispute." After investigating proposals by both parties, the arbitrator would select one of those proposals and could not alter the terms or resolve the dispute in any other manner. A 2008 agreement between AstraZeneca and MAP Pharmaceuticals had a similar baseball arbitration clause under which the arbitrator would determine which of the two proposals "is the most fair and reasonable to the Parties in light of the totality of the circumstances."

In 2011, Array Biopharma, who held the IP rights to a cancer drug, entered into a licensing agreement with ASLAN Pharmaceuticals. The agreement included a reciprocal option: either party could trigger a buyout at any time before "the expiration or termination of the agreement." It stipulated that either "Party (the 'Offeror') may trigger a buy-out by providing to the other Party (the 'Offeree'), notice [that] set[s] forth a lump sum payment amount (the 'Buy-Out Price')." Finally, the agreement stipulated that "the Offeree may elect, in its sole discretion ... to buy out the Offeror ... for the same lump sum Buy-Out Price that was offered by the Offeror."

The trend toward earlier-stage licenses implies that contracts will increasingly need to accommodate dynamic capabilities. We aim to answer the following questions. When (and how) can innovators use an array of contracts to accommodate dynamic capabilities? What are the benefits of mechanisms, such as baseball arbitration and reciprocal option clauses, that allow for turning the tables on one's partner? Can one improve the innovative reciprocal option contract and thereby bring it into the mainstream?

We make several contributions to the literature. First, the R&D licensing literature has traditionally focused on other dynamics in multi-stage partnerships, such as technical and market risks and moral hazard. We complement this literature by modeling the dynamic nature of capabilities (in the form of efforts to acquire new capabilities) and the uncertainty about how well newly acquired capabilities can be implemented. Second, we contribute to the licensing literature—which has focused on the more common (buyout and buyback) option contracts—by modeling two mechanisms not considered in that research stream: the widely adopted baseball arbitration clause and an innovative but underutilized reciprocal option. Third, on a prescriptive note, we demonstrate how a minor modification of this reciprocal option contract (viz., adding a "buyout price floor") substantially enhances its desirability. Our analysis reveals that managers should consider the implications of dynamic capabilities when structuring contracts for early-stage partnerships. The choice among contracts is driven by two factors: the cost or difficulty of obtaining a new capability, and the uncertainty in how well it can be implemented.

2. Literature Review

Our paper builds on two research streams: the literature on dynamic capabilities and the literature on R&D licensing. We review each of them in turn.

2.1. Dynamic Capabilities

Firms create unique value propositions by leveraging their physical, human, and organizational resources. These resources determine a firm's core competencies. *Dynamic capabilities* are organizational and strategic routines that managers use to alter their resource base (Eisenhardt and Martin 2000). This change can be achieved through various mechanisms: the acquisition of new resources, the increased integration of existing resources, and/or the shedding of resources no longer seen as valuable (Teece et al. 1997). We are interested in the firm's potential to gain new capabilities and in their effect on how that firm structures its partnerships. Thus we focus on the first of these mechanisms.

Firms can gain new resources through acquisitions. The literature has focused on pre- and post-acquisition factors that result in successful implementation of the newly acquired resources. Larsson and Finkelstein (1999) address pre-acquisition factors and find that cultural similarity and consistency of vision, as well as production and marketing complementarities across the two firms, are essential to the realization of potential synergies. Ranft and Lord (2002) suggest that the level of communication with members of the acquired firm—and the level of autonomy granted to them—determines the success of implementing the acquired firm's knowledge.

Firms also gain new capabilities through alliance interactions. An alliance not only fulfills the need for a missing capability but also allows the firm to understand that capability, after which it can move on to learning about and acquiring other capabilities. Indeed, Powell et al. (1996) find that firms forming alliances that allow them to learn about one capability subsequently form other types of alliances. Inkpen and Currall (2004) remark that, as one party in the alliance learns about and absorbs the other's capability, the former becomes less dependent on the latter.

Biopharmaceutical firms have pursued both avenues of attaining new capabilities. Helfat et al. (2009) report that Lilly has sought to expand its capabilities through alliances. In contrast, GlaxoSmithKline, Sanofi-Aventis, and Pfizer have pursued acquisitions.

Prior research has focused on how firms should or do acquire new capabilities. In contrast, we explore the implications of dynamic capabilities for the structure of early-stage alliances. Hence we do not distinguish between different *means* of acquiring a needed capability. Rather, we model the probability that a firm acquires a new capability as a function of its endogenous effort while accounting for the potentially less-than-seamless implementation of the acquired capability.

2.2. R&D Licensing

Most of the literature on R&D licensing is concerned with the use of various (typically financial) contract terms to address agency problems that arise during interactions between two firms. Thus that research addresses risk aversion, moral hazard, asymmetric information, and holdup problems. Jensen and Thursby (2001) study the use of equity and royalties to address moral hazard. More recent papers study additional contract terms and also combine asymmetric information with moral hazard (Crama et al. 2008, Xiao and Xu 2012, Savva and Taneri 2015). In their examination of the holdup problem, Bhattacharya et al. (2015) account for the Risk preferences of two partners. Empirical work has documented that biopharmaceutical partners structure their alliances to address asymmetric information, holdup concerns, and risk aversion (Taneri and De Meyer 2017).

A new product candidate typically takes more than a decade to proceed, through development stages, from idea to launch (Figueiredo et al. 2015). Such long development cycles across multiple stages entail significant technical and market uncertainty. Hence the literature has explored different avenues to introduce flexibility in contracting. Examples include the use of options, contract timing within the R&D process, renegotiation, and whether to contract on actions or deliverables.

It is well known that options facilitate the evaluation of uncertain, multi-stage projects (see e.g. Santiago and Vakili 2005). Various papers in the R&D licensing literature have studied the use of different types of options. Savva and Scholtes (2014) compare licensing to co-development with and without opt-out options in the presence of technical and commercial uncertainty. Bhattacharya et al. (2015) assess the effectiveness of buyout options versus "milestone" contracts in addressing moral hazard, risk aversion, and holdup problems. Crama et al. (2017) compare the effectiveness of buyback, buyout, and two-way options with respect to different control rights and timing decisions. Ziedonis (2007) finds empirical evidence that companies licensing university technologies are more likely to sign option contracts when the focal project is more uncertain or the companies are less able to evaluate the technology's potential. In the biopharmaceutical sector, Lerner and Malmendier (2010) study the use of termination options to address development uncertainty.

Several studies examine the impact of contract timing. Crama et al. (2017) find that it is optimal to delay partnerships for incremental innovation with little market uncertainty yet to sign contracts at an earlier stage for other projects—provided that control rights and options are appropriately assigned. Kalamas and Pinkus (2003) suggest that biopharmaceutical partnerships would be more effective if formed earlier than current industry practice. Garcia (2008) documents a trend toward earlier-stage licensing and notes the prominence of flexibility in such licensing agreements.

Some scholars explore how contract renegotiation allows the parties to respond to changes in the environment. According to Xiao and Xu (2012), renegotiation improves contracting outcomes by reallocating incentives to the party whose capability is most needed at a particular stage in the project; however, it also exacerbates the problems associated with information asymmetry. Crama et al. (2017) model costly renegotiation and find that it works similarly to delayed contracting for incremental innovations with a low level of market uncertainty.

Finally, Ryall and Sampson (2017) argue that contract mechanisms should be tailored to the underlying information structure. They find that it is best to contract on actions under full information whereas, under asymmetric information (and especially when there is ambiguity), the parties should prefer to contract on deliverables. Bhaskaran and Krishnan (2009) contrast contracting on the sharing of actions (development/innovation effort) and the sharing of deliverables (revenue). These authors establish that the choice between actions-based and deliverables-based contracts depends on the ratio of the two parties' effort costs and also on the project's uncertainty.

These papers show the importance of contracting nuances and flexibility given the uncertainties and information asymmetries inherent to the R&D process. A thread that runs through all the works just cited is that the need for flexibility is driven by technical and market risk. Another commonality is that, regardless of who owns what capabilities (and a party may own two), the parties do not acquire new capabilities. Yet the possibility of acquiring new capabilities is precisely the focus of our paper. We are interested in dynamic capabilities because R&D partnerships are frequently of long duration. As established in the literature on dynamic capabilities (see Section 2.1), firms are continually acquiring new capabilities—especially firms in high-tech industries (Teece 2007), which are of particular relevance to this paper. We therefore discuss how to make contracts more flexible in light of future, endogenous, and uncertain changes to the parties' respective capabilities and to their need for each other.

3. Model

This section is divided into three parts. First, we characterize capability acquisition efforts and the two resulting uncertainties from those efforts. Second, we characterize value creation efforts by either a single party developing the product in-house—contingent on that party's capability acquisition outcome—or two parties jointly developing the product. Third, we formulate and solve the first-best capability acquisition efforts and allocation decisions of a central planner.

3.1. Capability Acquisition Efforts

Our model consists of an innovator and a partner. The two parties bring different capabilities to the table (e.g., drug development, design of clinical trials, expertise in a particular therapeutic area, class of molecules, slow-release technologies). Either party can exert efforts to attain the capability of the other after an agreement is signed. In the absence of an agreement, the innovator—who owns the innovation's IP rights—can attempt to attain her partner's capability. The efforts of the innovator and the partner are denoted by probabilities p and q, respectively. The cost of effort is quadratic in the chosen effort: $cp^2/2$ and $cq^2/2$, where $c > 0$ represents the difficulty of acquiring a new capability. Thus there is uncertainty about whether or not capability acquisition will be successful, and higher effort levels increase the likelihood of success.

Yet even if one assumes that a party is successful in acquiring the other's capability, the former may not be able to implement that capability as well as the latter. So in addition to uncertainty about whether acquisition efforts will translate into a new capability, there is also a second uncertainty about its implementation. Our model represents the second uncertainty via the parameter $\Gamma \in \{\gamma, 1\}$, where $0 < \gamma < 1$. When $\Gamma = 1$, the new capability has been acquired and implemented in full; thus the acquiring party is just as effective as the other party. When $\Gamma = \gamma$, the new capability has been acquired but not implemented in full; hence the acquiring party is *not* as effective as the other party. We assign equal probabilities to the full and partial implementation of an acquired capability. As a result, the coefficient of variation of the value that can be attained by a single party who has acquired the other's capability is $\frac{1-\gamma}{1+\gamma}$; a smaller γ implies greater uncertainty in value due to implementation concerns. Hence we refer to the parameter γ as the *implementation uncertainty*.

3.2. Value Creation Efforts

The two parties have complementary capabilities that, together, enhance the project's value. We capture complementary capabilities through a Cobb–Douglas function of the form $v(P,Q) = AP^{1/2}Q^{1/2}$. The constant A is a measure of efficiency in converting efforts to value and is determined by how well each capability has been implemented by the party or parties exerting effort P (resp. Q) in the innovator's (resp. partner's) original capability. Hence we adopt the form $A = (\Gamma_P \Gamma_Q)^{1/2}$. We assume that exerting effort P (resp. Q) has an associated quadratic cost of the form $\frac{kP^2}{8}$ (resp. $\frac{kQ^2}{8}$).[2]

So when one party has attained the other's capability and then plans to exert effort P *and* effort Q, its optimization problem is given by $\max_{P,Q\geq 0} V_2(P,Q,\Gamma) = \sqrt{\Gamma PQ} - \frac{kP^2}{8} - \frac{kQ^2}{8}$, where

[2] Our results are generalizable to any $A(\Gamma_P, \Gamma_Q) > 0$ that is increasing in Γ_i ($i \in \{P,Q\}$) and to any form of convex costs kP^ρ/κ and kQ^ρ/κ with $\rho > 1$, $k > 0$, and $\kappa > 0$.

Γ represents how well that party has implemented its new capability.[3] The optimal efforts by that party are given by $P^* = Q^* = \frac{2\sqrt{\Gamma}}{k}$, and it earns

$$V_2(P^*, Q^*, \Gamma) = \frac{\Gamma}{k}. \tag{1}$$

Equation (1) shows that value creation efforts depend on the capability acquisition outcome, which in turn depends on capability acquisition efforts. When the newly acquired capability is implemented in full ($\Gamma = 1$), value creation efforts generate a value of $V_2(P^*, Q^*, 1) = \frac{1}{k}$. When implemented partially ($\Gamma = \gamma$), those efforts generate $V_2(P^*, Q^*, \gamma) = \frac{\gamma}{k} = \gamma V_2(P^*, Q^*, 1) < \frac{1}{k}$.

When both parties bring the product to market jointly, however, each capability is implemented in full (by the party exerting the effort) and the product's value is given by $\sqrt{PQ}$. It is straightforward to show that the value created is highest when the two parties split that value equally.[4] An equal split is consistent with practice: among all agreements in the Thomson Reuters Recap Database that include a profit-sharing clause, nearly two thirds of them divide the profit equally. In that case, the innovator and her partner simultaneously solve the respective optimization problems $\max_{P \geq 0} V_1(P, Q) = \frac{1}{2}\sqrt{PQ} - \frac{kP^2}{8}$ and $\max_{Q \geq 0} V_1(P, Q) = \frac{1}{2}\sqrt{PQ} - \frac{kQ^2}{8}$. The optimal efforts are then $P^* = Q^* = \frac{1}{k}$, and each party earns $V_1(P^*, Q^*) = \frac{3}{8k}$ for a total value of

$$2V_1(P^*, Q^*) = \frac{6}{8k}. \tag{2}$$

We can draw two conclusions from equations (1) and (2). First, a party that has attained the other's capability—and has implemented it *in full*—always creates more value than the two parties jointly developing the product: $\frac{1}{k} > \frac{6}{8k}$. This outcome reflects the presence of moral hazard concerns when the two parties work together and the absence of those concerns when both efforts are made by a single party that has fully implemented its new capability. Second, a party that has attained the other's capability but has only implemented it *partially* may create either more or less value than the two parties jointly developing the product; whether or not $\frac{\gamma}{k} > \frac{6}{8k}$ depends on the value of γ. Thus we compare losses from partial implementation of a new capability to the losses due to moral hazard. The relative magnitudes of these losses will determine whether more value is created when the two parties collaborate on value creation or when one party, who has only partially implemented its new capability, makes both efforts.

A more general representation of our model's salient features abstracts from the Cobb—Douglas function by defining the value attained by a single party that has implemented its new capability

[3] Here the subscript to Γ is omitted because we always have $\Gamma = 1$ for the party's original capability.

[4] Documentation for these results is available from the authors upon request.

in full (resp. partially) as V_2 (resp. γV_2). We denote the value attained by each party when they jointly develop the product as V_1 for a total value of $2V_1$, where $2V_1 < V_2$. All subsequent results using V_1 and V_2 can thus be interpreted by substituting $V_2 = \frac{1}{k}$ and $V_1 = \frac{3}{8k}$. The notation for all models is summarized in Table 1.

	Decisions		*Parameters*
p	Capability acquisition effort by innovator	c	Capability acquisition effort cost factor
q	Capability acquisition effort by partner	k	Value creation effort cost factor
P	Value creation effort in innovator's original capability	Γ	Capability acquisition outcome, $\Gamma \in \{\gamma, 1\}$, $0 < \gamma < 1$
Q	Value creation effort in partner's original capability	V_1	Value each party obtains from joint development
B	Exercise/strike price	V_2	Value of product developed by a single party with $\Gamma = 1$

Table 1 Notation used in models

3.3. Central Planner's Perspective

We assume that the central planner sets the capability acquisition efforts but *not* the value creation efforts. The reason is that our primary interest lies in investigating the optimal capability acquisition efforts. If the central planner sets the value creation efforts then there would be no moral hazard. In that case, neither would there be any incentive to incur capability acquisition costs; hence capability acquisition efforts would (trivially) be set to zero.

Anticipating the potential results of the value creation stage, the central planner maximizes social welfare by setting the socially optimal (first-best) capability acquisition effort levels for the two parties and then determining the party (or parties) to which the product is allocated once the effort outcomes are realized. We can therefore write the central planner's objective function as

$$\max_{0 \le p,q \le 1} \left(\frac{3}{4}pq + \frac{1}{2}(p(1-q) + q(1-p)) \right) V_2 + \left(\frac{pq}{4} + \frac{1}{2}(p(1-q) + q(1-p)) \right) \max\{\gamma V_2, 2V_1\}$$
$$+ (1-p)(1-q)2V_1 - \frac{cp^2}{2} - \frac{cq^2}{2}. \tag{3}$$

The first term captures the case when at least one party has acquired the other's capability in full. The second term captures the case when (a) at least one party has acquired the other's capability but (b) neither party has acquired the other's capability in full. In this case, the "max" operator accounts for the central planner's allocation decision by allocating the product according to whether the product is more valuable in the hands of a single party or two parties. If $\gamma V_2 > 2V_1$ then the product is allocated to a single party (which has acquired the other's capability with $\Gamma = \gamma$); otherwise, the product is brought to market by both parties jointly and the total value is $2V_1$. The third term captures the case when neither party has acquired the other's capability, and the last two terms are (respectively) the innovator's and partner's effort costs.

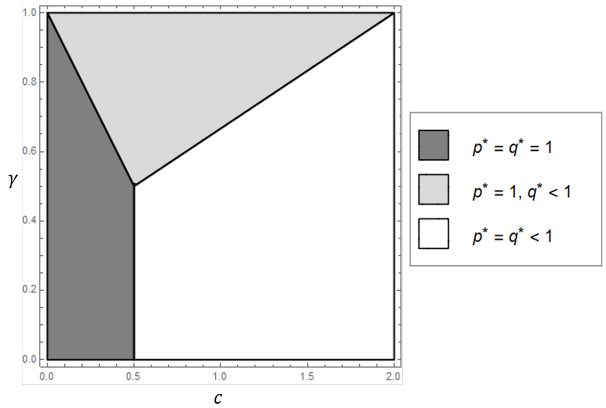

Figure 1 **Central planner's execution: First-best effort levels**

PROPOSITION 1. *A central planner sets asymmetric efforts, with only one party exerting full effort whenever* $(1-\gamma)V_2 \leq 4c \leq V_2(1+3\gamma) - 8V_1$*. Otherwise, the central planner sets symmetric efforts* $p = q = 1$ *whenever* $4c \leq \min\{(1-\gamma)V_2, V_2 - 2V_1\}$ *and* $p = q < 1$ *whenever* $4c > \max\{V_2 - 2V_1, V_2(1+3\gamma) - 8V_1\}$.

All proofs are given in the eCompanion. Proposition 1 indicates that, despite both parties being symmetric in their parameters at the outset, it may be socially optimal to induce asymmetric effort levels. A graphical representation of the conditions in Proposition 1 is provided by Figure 1.[5]

We first note that, for low effort cost, the central planner sets both efforts to $p^* = q^* = 1$ and then allocates the product to the party or parties creating the most value. This approach yields an inexpensive hedge against the possibility of a low γ. As the cost of effort increases, such high efforts can be justified only by higher implementation uncertainty (i.e., lower γ).

Now suppose that acquiring the capability is difficult (i.e., c is high). Then the quadratic nature of effort costs implies that a marginal unit of effort is less costly when effort is low; as a consequence, splitting effort across two parties reduces overall costs. Therefore, if c is high then the central planner reduces individual effort to $p^* = q^* < 1$ and "spreads" effort without severely reducing the likelihood of at least one party attaining both capabilities. In effect, if c is high then a different type of hedge—namely, against *neither* party obtaining the other's capability—also becomes important.

It is interesting that there exists a region—with moderate effort cost c and low implementation uncertainty (high γ)—where the central planner sets asymmetric efforts. In that region, the cost is not low enough to justify setting the effort of both parties to $p = q = 1$, especially since implementation uncertainty is low. Yet the high γ also makes it desirable for the product *not* to be

[5] All figures use the same parameters: $V_1 = 1$ and $V_2 = 4$.

launched by the two parties together because $2V_1 < \gamma V_2$. Thus the need to ensure that at least one party acquires the other's capability induces the central planner to set the effort of one party (say, the innovator) to 1. A nonzero effort is set for the other party to hedge against the $\Gamma = \gamma$ outcome.

In other words, the central planner aims to achieve two types of hedge: (i) a *failure hedge* against neither party obtaining the other's capability; and (ii) an *implementation hedge* against uncertainty in the implementation outcome. If γ is high then the failure hedge is more critical and so, for a wider range of effort cost, the central planner sets at least one party's efforts to the maximum. When γ is low, the implementation hedge is crucial; hence effort is spread evenly between both parties to increase the likelihood that at least one of them achieves full implementation. In this case, if c is low then the probability of success is set to 1 for both parties ($p = q = 1$); for higher c, that probability is set to a value lower than 1 ($p = q < 1$) and decreases as c increases.

Our analysis of the central planner's problem hints at the key tensions an innovator faces when selecting among and optimizing the parameters of various contracts. The first trade-off concerns the allocation decision: make it too easy to take development in-house, and the less capable party may end up with the product; make it too difficult, and risk ending up with joint development—and the associated moral hazard loss—even if more value would have been created by a single party. The second trade-off is with regard to capability acquisition efforts: a contract that induces too little effort does not provide a sufficient hedge against failure and partial implementation, and one that induces too much effort destroys value by incurring too much cost relative to the value of the hedge it provides.

4. Innovator's Contract Choices

In this section, we investigate the various contracts and compare the value they generate for the innovator. We start with the case of delayed contracting. Then we explore the following contract structures: a dual buyout–buyback option, baseball arbitration, and reciprocal option. Figure 2 plots the timelines and illustrates the two parties' interaction under the different contract types.

If no contract is signed upfront at time $t = 0$, then only the innovator exerts capability acquisition effort (p) at time $t = 1$. Once the result of this effort is revealed at $t = 2$, the innovator decides whether (or not) to contract with a partner at time $t = 3$. Payoffs are realized at $t = 4$. Alternatively, the innovator and partner sign a contract at time $t = 0$. This contract specifies the type of contract signed, the side payment F from the partner to the innovator, and—in the case of a dual-option contract—the option exercise price B. At time $t = 1$, the two parties decide on their respective effort levels p and q. The outcome of these efforts is realized at $t = 2$. We assume that each party can

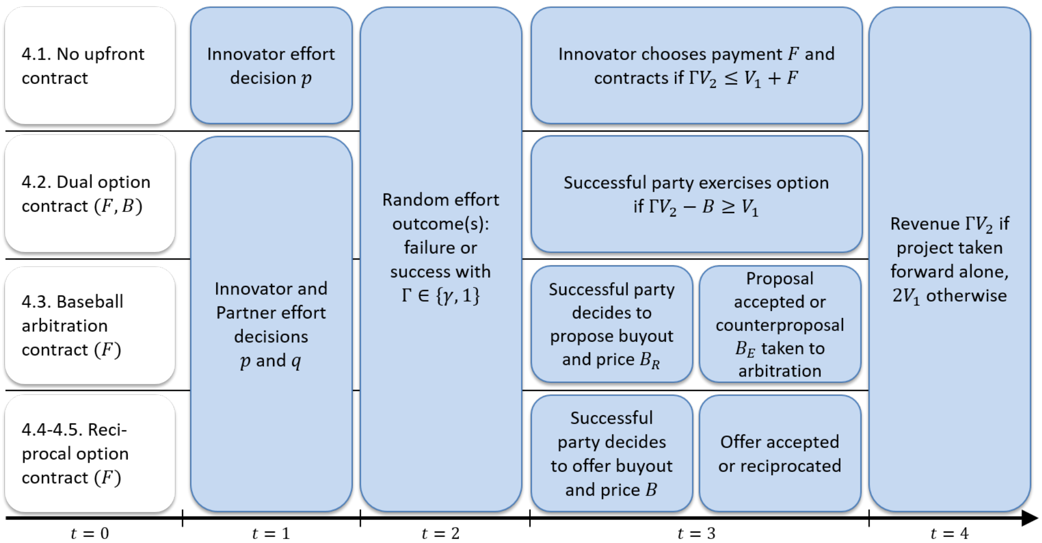

Figure 2 Timelines under different contract structures

observe whether the other has obtained a new capability but cannot observe how well it has been implemented. Hence, there is asymmetric information about implementation. These circumstances are akin to, for example, knowing that a company acquired a small biotech with specific capabilities but not knowing how well the physical and human assets of that biotech have been integrated into the acquiring firm. At time $t = 3$, the parties make a decision about whether or not to continue with joint development. With a dual buyout–buyback option, either party can choose to exercise the option at the pre-determined strike price B. If both parties want to exercise the option, then whichever party makes the offer first (with probability 1/2) buys out the other. With baseball arbitration, either party can propose a price B^R to buy out the other party. The party that makes a proposal first becomes the proposer, and the other party (the proposee) can either choose to accept that proposal or go to arbitration with a counterproposal to buy out the proposer for B^E. The arbitrator decides which proposal prevails. Under a reciprocal option contract, either party can make an offer B whose value was not pre-specified. The party that makes an offer first becomes the offeror, and the other party (the offeree) decides whether to accept the offer or to reciprocate (i.e., to buy out the offeror at the same price B). Payoffs are realized at $t = 4$.

4.1. No Upfront Contract

With no upfront contract, the innovator makes an individual effort upfront and contracts with a partner only if needed, after her effort outcome is realized. Then the innovator's optimization is

$$\max_{0 \leq p \leq 1, 0 \leq F \leq V_1} \frac{1}{2} p V_2 + \frac{1}{2} p \max\{\gamma V_2, V_1 + F\} + (1 - p)(V_1 + F) - \frac{cp^2}{2}.$$

The innovator's optimal actions are described in Lemma 1.

Lemma 1. *With no upfront contract, the innovator's optimal effort level is* $p_N = 1$ *for* $c \leq \frac{V_2+\max\{\gamma V_2, 2V_1\}-4V_1}{2}$ *and is* $p_N < 1$ *otherwise. The innovator always sets* $F = V_1$ *and contracts with the partner only when* (a) *she achieves partial implementation and* $\gamma \leq \frac{V_2}{2V_1}$ *or* (b) *she fails to acquire the partner's capability.*

Since the innovator contracts with the partner only if $\Gamma V_2 \leq V_1 + F$, it follows that setting the fixed fee to its upper bound (or $F = V_1$) maintains the socially optimal product allocation decision—namely, that the partners develop jointly if $\gamma V_2 \leq 2V_1$ or if she fails to acquire the missing complementary capability. Despite being able to induce the socially optimal allocation, the innovator's effort decision differs from the central planner's effort decisions described previously; hence the innovator (weakly) overinvests in effort because she is alone in exerting effort and so cannot benefit from either an implementation hedge or a failure hedge.[6]

4.2. Dual Buyout–Buyback Option

It can be shown that, in our setting, a single buyout or buyback option where only one party has the right to buy out the other is dominated by a dual buyout–buyback option where either party can buy out the other.[7] Hence we model the dual buyout–buyback option as the first alternative to not signing an upfront contract. With this option, the partner has the right to buy out the innovator and the innovator has the right to buy back rights to the product from the partner at a pre-determined price B. The contract structure is optimized by solving the game via backward induction. In the *first* of three steps, the partners decide whether or not to exercise their respective options. We remark that the option will never be exercised if $V_2 - B < V_1$; thus we limit our analysis to the case where $B < V_2 - V_1$. To describe the remaining cases, we introduce an indicator function $d \in \{0, 1\}$ such that

$$d = \begin{cases} 1 & \text{if } \gamma V_2 - B > V_1, \\ 0 & \text{if } \gamma V_2 - B \leq V_1. \end{cases}$$

When $d = 1$ the option is exercised by a party who has attained either $\Gamma = \gamma$ or $\Gamma = 1$, whereas when $d = 0$ the option is not exercised unless a party has attained $\Gamma = 1$. If neither party exercises their option then the product is developed jointly. If only one party wants to exercise its option, the exercising party takes sole ownership of the product. If both parties want to exercise their option, then the exercise order is assigned randomly.

[6] When $F = V_1$, the partner receives zero utility from the contract. Therefore, if the innovator cannot set the highest admissible fixed fee then further value could be lost as compared with the social optimum, since the allocation decision will be suboptimal whenever $2V_1 > \gamma V_2 > V_1 + F$.

[7] Results from comparing single and dual buyout–buyback options are available from the authors upon request.

In the *second* step, the innovator and partner—while accounting for their own and the other party's anticipated exercise decisions—optimize their efforts so as to maximize their value. Because the parties' objective functions are symmetric, we present only the innovator's. Formally, we write

$$\begin{aligned}\max_{0\le p\le 1} pq\Bigg(& d\bigg(\frac{1}{2}\big({(\gamma V_2-B)}/{2}+{B}/{2}\big)+\frac{1}{2}\big({(V_2-B)}/{2}+{B}/{2}\big)\bigg)\\ &+(1-d)\bigg(\frac{1}{4}V_1+\frac{1}{4}B+\frac{1}{4}(V_2-B)+\frac{1}{4}\big({(V_2-B)}/{2}+{B}/{2}\big)\bigg)\Bigg)\\ &+p(1-q)\big(d\big({(V_2-B)}/{2}+{\gamma V_2-B}/{2}\big)+(1-d)\big({(V_2-B)}/{2}+{V_1}/{2}\big)\big)\\ &+(1-p)q\big(dB+(1-d)({B}/{2}+{V_1}/{2})\big)+(1-p)(1-q)V_1-\frac{cp^2}{2}. \end{aligned} \tag{4}$$

The first two lines capture the case when both parties attain the other's capability. In this case, if $d=1$ then the parties exercise their option regardless of their implementation outcome. If the innovator has only partially implemented her newly acquired capability (with probability $1/2$) then her payoff is $\gamma V_2 - B$ when she is first to make the offer or B when the partner makes the first offer (here each party is equally likely to make the first offer). Under full implementation, the payoffs are $V_2 - B$ and B, respectively. If $d=0$ then one of four combinations of events can occur, each with probability $1/4$. No offer is made if both parties attain only partial implementation, leading to payoff V_1. If one party has achieved full implementation but the other has not, then the former's payoff is B and the latter's is $V_2 - B$. If both parties attain full implementation, either party could be the first to make an offer with equal probability: the first mover and second mover obtain $V_2 - B$ and B, respectively. The third line of the objective function captures the case when only the innovator has attained the capability of the partner in a similar fashion. On the fourth line, the first term captures the case when only the partner has attained the capability of the innovator, the second term captures the case when neither party has attained the other's capability, and the last term captures the innovator's effort cost.

Let $p_O(B)$ and $q_O(B)$ denote (respectively) the innovator's and partner's optimal effort as a function of B. Then, in the *third* step, the strike price B is set to maximize social welfare—the sum of the payoffs of the innovator and the partner—as seen here:

$$\begin{aligned}\max_{B\ge 0} p_O(B)q_O(B)&\bigg(d\bigg(\frac{\gamma V_2}{2}+\frac{V_2}{2}\bigg)+(1-d)\bigg(\frac{2V_1}{4}+\frac{V_2}{4}+\frac{V_2}{4}+\frac{V_2}{4}\bigg)\bigg)\\ &+\big(p_O(B)(1-q_O(B))+q_O(B)(1-p_O(B))\big)\bigg(d\bigg(\frac{V_2}{2}+\frac{\gamma V_2}{2}\bigg)+(1-d)\bigg(\frac{V_1}{2}+\frac{V_2}{2}\bigg)\bigg)\\ &+(1-p_O(B))(1-q_O(B))2V_1-\frac{cp_O(B)^2}{2}-\frac{cq_O(B)^2}{2}.\end{aligned}$$

The social welfare function follows the same structure as equation (4). Note that the strike price B cancels out in the social welfare function because it is simply a transfer from one party to the other. Having created the maximum social welfare, there will always exist a side payment that can satisfy the participation constraints of both parties provided that more value is created than under the case with no upfront contract. The outcome of this optimization is summarized in Lemma 2.

LEMMA 2. *With a dual buyout–buyback option, it is optimal to set a low strike price of*

$$B = \frac{(1+\gamma)V_2}{4} - \frac{c((1+\gamma)V_2 - 4V_1)}{2((1+\gamma)V_2 - 4V_1 + 2c)} \leq \gamma V_2 - V_1$$

if $\gamma \geq \gamma_1$ *and* $c < c_1$ *or if* $\gamma \geq \gamma_2$ *and* $c > c_1$. *Otherwise, it is optimal to set a high strike price of*

$$B = \max\left\{\gamma V_2 - V_1 + \varepsilon, \frac{V_2}{2} - \frac{2c(V_2 - 2V_1)}{V_2 - 2V_1 + 4c}\right\}.$$

Lemma 2 shows that it may be optimal to set the strike price B at one of two levels. Note that all boundaries $(\gamma_1, \gamma_2, c_1)$ are defined in the proof. When the strike price is *high*, only a party that attains $\Gamma = 1$ exercises the option. This means that if each party has acquired the other's capability, but only one with full implementation, then a high strike price allows for the product to be allocated to the party that can create the most value. When the strike price is *low*, the option can be exercised by any party that attains the other's capability regardless of implementation outcome (i.e., the option is exercised for $\Gamma = \gamma$ *and* $\Gamma = 1$). It follows that, if each party has acquired the other's capability but with different implementation outcomes, a low strike price does not necessarily allocate the product to the party best able to create the most value.

PROPOSITION 2. *The dual buyout–buyback option strictly dominates not signing a contract upfront if and only if* $c > \frac{(1+\gamma)V_2}{2} - 2V_1$ *or* $\gamma \leq \gamma_3$.

Proposition 2 shows that a dual buyout–buyback option often—though not always—outperforms delayed contracting. The dual buyout–buyback contract induces efforts from both parties; that is not possible with delayed contracting, where only the innovator exerts effort. As illustrated earlier, inducing both parties to exert effort yields an implementation and/or failure hedge. When implementation uncertainty is high (i.e., γ is low), simultaneous efforts allow the selection of the better of two capability acquisition outcomes. When the cost of effort is high, simultaneous efforts can also reduce that cost by lowering the individual effort level needed to achieve the same overall probability of success—or to improve the overall probability of success at the same total cost. Any additional value created by such hedges can be split across the parties through side payments, which is why the innovator prefers the dual buyout–buyback contract to delayed contracting.

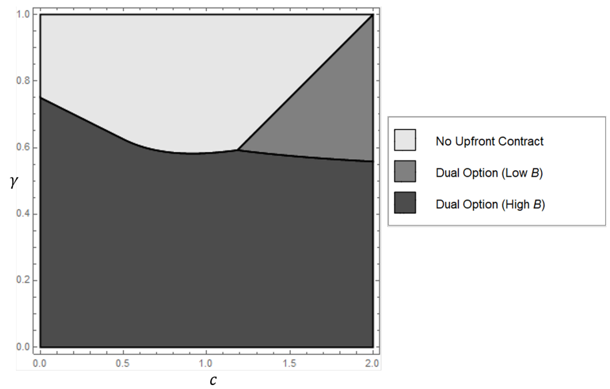

Figure 3 **Optimal contracting choice with a dual option**

Figure 3 also distinguishes between regions where it is optimal to charge a high versus a low strike price (B). The choice between a low and a high strike price depends on trade-offs between the severity of the two contracts' distinct downsides, as we now explain.

With a *high* strike price, it could be that the option is not exercised even when at least one party acquires the other's capability. This happens in two scenarios: (i) when both parties have attained $\Gamma = \gamma$; and (ii) when one has attained $\Gamma = \gamma$ but the other has failed to acquire the new capability. In both scenarios, the parties' payoffs are $\{V_1, V_1\}$ for a total of $2V_1$ (excluding side payments). When $2V_1 < \gamma V_2$ (i.e., γ is high), some value is lost. In addition, the higher γ is, the more value is lost if a high strike price prohibits a party with $\Gamma = \gamma$ from exercising the option. This issue does not arise when $2V_1 \geq \gamma V_2$ (i.e., γ is low) because the parties then prefer a payoff of V_1 each. Therefore, a high strike price is preferred when γ is low. With a *low* strike price, it could be that the option is exercised—and the product is developed by—the less capable party. That happens with probability $1/2$ when one party attains $\Gamma = \gamma$ and the other $\Gamma = 1$. Then both parties wish to exercise their respective options, and the party who has partially implemented the new capability might act first. Although that outcome is always suboptimal, this is less of an issue when γ is high—in which case a low strike price is preferable. Our comparison demonstrates the first trade-off mentioned at the end of Section 3.3. An innovator, when restricted to traditional option contracts with a pre-determined strike price, chooses the less detrimental of two downsides: joint development when more value would have been created by a single party (when the strike price is high) versus the less capable party taking development in-house (when the strike price is low).

Finally, we observe from Figure 3 that it may still be optimal for the innovator *not* to sign an upfront contract under medium to low c and high γ. There are two reasons for this result. First, the innovator always acquires the other party's capability in this region because the combination of a relatively low c and a high γ induces the optimal effort $p=1$, which eliminates the need to induce partner effort as a hedge against failure. Second, a hedge against implementation uncertainty (the $\Gamma=\gamma$ outcome), which a partner's effort would provide, is less valuable when γ is high.

4.3. Baseball Arbitration

In the absence of a pre-determined strike price, either party may propose to buy out the other. The recipient of the proposal can choose to accept it. If the recipient is not satisfied with the proposal, then baseball arbitration clauses provide a framework for the recipient to make a counterproposal, after which both proposals are submitted to an arbitrator. We solve this contract structure by backward induction, starting with the decision of the arbitrator, followed by the determination regarding the proposal vs. the counterproposal, and finally the effort level selection by both parties. For brevity, we omit the detailed formulations.

Making the Proposal and Determining the Price. We label the first party to make a proposal the *proposer* (R) and the recipient of that proposal the *proposee* (E). The proposee can either accept the proposal, B^R, or approach a domain expert arbitrator with a counterproposal to buy out the proposer at a price, $B^E > B^R$. The arbitrator's decision on which of the two proposals prevails is final. The arbitration process has a cost $0 < \alpha < \frac{V_2-\gamma V_2}{2}$ for each party.[8] We make the following assumptions about the arbitrator. First, the arbitrator observes Γ for each party. Second, the arbitrator chooses the proposal that attains a cooperative outcome by minimizing the maximum dissatisfaction of the two parties (see e.g. Barron 2013). Third, when the two parties' levels of dissatisfaction are equal, the arbitrator chooses the higher proposal. The dissatisfaction of a party whose proposal is not chosen by the arbitrator is given by the difference between the payoff they would have attained with their proposal and the payoff they attain with the chosen proposal— that is, by $D^R=(\Gamma^R V_2 - B^R) - B^E$ and $D^E=(\Gamma^E V_2 - B^E) - B^R$ for the proposer and the proposee, respectively.

LEMMA 3. *It is optimal for a proposer who has attained* $\Gamma^R=1$ *to propose* $B^R=\frac{V_2-\alpha}{2}+\varepsilon$, *where* $\varepsilon\to 0^+$. *This proposal is accepted by proposees of either type. For a proposer who has attained* $\Gamma^R=\gamma$, *it is optimal to propose any* $B^R\in\left(\frac{\gamma V_2-\alpha}{2}, \frac{V_2-\alpha}{2}\right)$. *This proposal is accepted by proposees of type* $\Gamma^E=\gamma$ *but not by those of type* $\Gamma^E=1$. *A proposee for whom* $\Gamma^E=1$ *goes to arbitration with a counterproposal* $B^E=B^R+\delta$, *where* $\delta\to 0^+$ *and the arbitrator decides in favor of the proposee's counterproposal.*

[8] The condition $\alpha<(V_2-\gamma V_2)/2$ ensures that the total cost of arbitration, 2α, is less than the value created when the arbitrator allocates the project to a party who attained $\Gamma=1$ instead of to a party who attained $\Gamma=\gamma$. Otherwise, arbitration would destroy value.

Lemma 3 implies that a proposer that has fully implemented its new capability makes a proposal that would be accepted by a party who has attained full or partial implementation. Once accepted, this proposal would allow the proposer to attain a payoff of $\frac{V_2+\alpha}{2}-\varepsilon$. It is interesting that, because the proposee wants to avoid arbitration costs, the existence of a costly arbitration process allows the proposer not only to make a lower proposal but also to attain a payoff that exceeds half of the project's value. This excess payoff increases with the arbitration cost. A proposer who has partially implemented a new capability makes a proposal that would be accepted by a party who has attained partial implementation but is taken to arbitration by a party who has attained full implementation, for whom the benefits of owning the project in its entirety outweigh the arbitration costs.

PROPOSITION 3. *When each party has acquired the other's capability, the optimal proposal strategies are as follows.*

1. *If* $3\gamma V_2 \leq V_2 + 4V_1$: *An offer is made whenever* $\Gamma = 1$ *but no offer is made otherwise.*
2. *If* $3\gamma V_2 > V_2 + 4V_1$: *An offer is made whenever* $\Gamma = 1$; *however, if* $\Gamma = \gamma$ *then the parties play a mixed strategy whereby an offer is made with probability* $\pi = \frac{V_2(3\gamma-1)-4V_1}{2\gamma V_2-4V_1}$.

Proposition 3 shows that a party who achieves full implementation always makes a proposal. That is because being the first mover in this case allows the successful party to achieve a payoff of $\frac{V_2+\alpha}{2}$, which is strictly greater than half of the value created. Yet when a party achieves only partial implementation of the other party's capability, the former may prefer not to make a proposal if the value with partial implementation is low. The reason is that the excess return above half of the value created ($\frac{\gamma V_2+\alpha}{2}$) in case the proposal is accepted is not enough to compensate for (a) the possibility of a counterproposal and its associated lower payoff and (b) the missed opportunity of receiving a better proposal in the event that the other party has attained full implementation. When the value with partial implementation is large enough, what emerges is a mixed strategy that balances the benefits and costs mentioned here. When only one party achieves the other's capability, the former exploits that circumstance to make a proposal $B^R = 0$ because the latter, unsuccessful party cannot further the project on its own.

Choosing the Effort Level. In this step, the two parties choose their effort level to maximize their respective payoffs while taking into account their own and the other party's subsequent proposal and counterproposal behavior as well as the other party's anticipated best-response effort level. We illustrate the innovator's payoff function here for the three possible cases of γ:

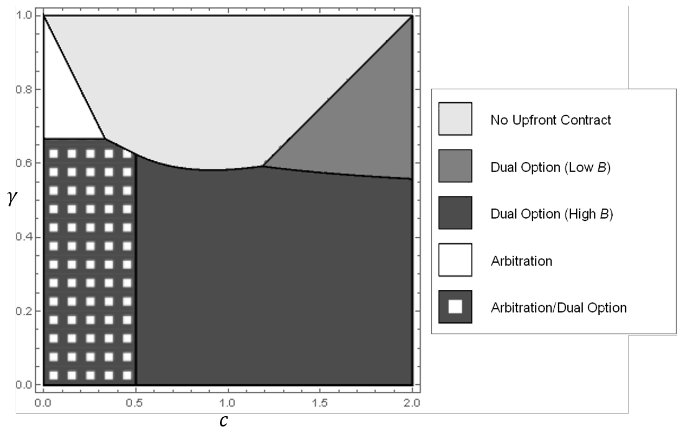

Figure 4 **Optimal contracting choice with dual option and baseball arbitration ($\alpha = V_2(1-\gamma)/4$)**

$$\omega_A^I = \begin{cases} \frac{pq}{4}\left((1-\pi)^2 V_1 + 2(1-\pi)\pi\frac{\gamma V_2}{2} + \pi^2\frac{\gamma V_2}{2}\right) + \frac{pq}{4}\left((1-\pi)\frac{V_2-\alpha}{2} + \pi\left(\frac{1}{2}\frac{V_2-\alpha}{2} + \frac{1}{2}\left(\frac{\gamma V_2-\alpha}{2} - \alpha\right)\right)\right) & \\ \quad + \frac{pq}{4}\left((1-\pi)\frac{V_2+\alpha}{2} + \pi\left(\frac{1}{2}\frac{V_2+\alpha}{2} + \frac{1}{2}\left(V_2 - \alpha - \frac{\gamma V_2 - \alpha}{2}\right)\right)\right) + \frac{pq}{4}\frac{V_2}{2} & \text{if } \gamma V_2 \geq \frac{V_2+4V_1}{3}, \\ \quad + p(1-q)\left(\frac{1}{2}\gamma V_2 + \frac{1}{2}V_2\right) + (1-p)(1-q)V_1 - \frac{cp^2}{2} & \\ pq\left(\frac{V_1}{4} + \frac{3}{4}\frac{V_2}{2}\right) + p(1-q)\left(\frac{1}{2}\gamma V_2 + \frac{1}{2}V_2\right) + (1-p)(1-q)V_1 - \frac{cp^2}{2} & \text{if } \frac{V_2+4V_1}{3} \geq \gamma V_2 \geq V_1, \\ pq\left(\frac{V_1}{4} + \frac{3}{4}\frac{V_2}{2}\right) + p(1-q)\left(\frac{1}{2}V_1 + \frac{1}{2}V_2\right) + (1-p)q\frac{1}{2}V_1 + (1-p)(1-q)V_1 - \frac{cp^2}{2} & \text{if } \gamma V_2 < V_1. \end{cases}$$

The objective function includes the payoff when both are successful—playing either a mixed strategy ($\gamma V_2 \geq \frac{V_2+4V_1}{3}$) or a pure strategy ($\gamma V_2 < \frac{V_2+4V_1}{3}$)—followed by the payoffs when the innovator is successful yet the partner is not, then the payoff where the partner is successful but the innovator is not (which is null when $\gamma V_2 \geq V_1$), and finally the payoff when neither is successful. The last term is the cost of effort. The two parties optimize their efforts to maximize their payoff. We use their response functions to find the equilibrium efforts (p_A, q_A), which are given in Lemma 4.

LEMMA 4. *Under a baseball arbitration contract, the optimal efforts are as follows.*

1. *If* $\gamma V_2 > \frac{V_2+4V_1}{3}$, *then* $p_A = q_A = \min\left\{1, \frac{16(\gamma V_2 - 2V_1)((1+\gamma)V_2 - 2V_1)}{64V_1(V_1-c) - 8(V_1(1+7\gamma) - 4c\gamma V_2 + (1+\gamma(2+13\gamma))V_2^2 - 4\alpha(4V_1 + V_2(1-3\gamma))}\right\}$.
2. *If* $V_1 < \gamma V_2 < \frac{V_2+4V_1}{3}$, *then* $p_A = q_A = \min\left\{1, \frac{4((1+\gamma)V_2 - 2V_1)}{(1+4\gamma)V_2 - 10V_1 + 8c}\right\}$.
3. *If* $\gamma V_2 < V_1$, *then* $p_A = q_A = \min\left\{1, \frac{4(V_2 - V_1)}{V_2 - 2V_1 + 8c}\right\}$.

We can now proceed to compare the contract value under baseball arbitration to the contracting choices studied previously. The results are summarized in Proposition 4.

PROPOSITION 4. *Baseball arbitration is equivalent to the dual-option contract for* $c \leq \frac{V_2 - 2V_1}{4}$ *and* $\gamma \leq \min\left\{\frac{V_2+4V_1}{3V_2}, \gamma_3\right\}$. *Baseball arbitration is strictly better than all other contract forms for* $\gamma \geq \frac{V_2+4V_1}{3V_2}$ *and* $c \leq \frac{(1-\gamma)V_2(8V_1 + V_2(1-5\gamma)) - 4\alpha(4V_1 + V_2(1-3\gamma))}{8(\gamma V_2 - 2V_1)}$.

Proposition 4 and Figure 4 illustrate that using a baseball arbitration clause is optimal when c is low and γ is high; furthermore, it is equivalent to using a dual-option contract for lower values of

γ and low cost. The equivalence of these two contracts is intuitive in light of the parties' proposal and effort behaviors. For lower γ, the optimal proposal strategy under baseball arbitration is the pure strategy in which a party with partial implementation does not make a proposal yet a party with full implementation does. In general, the penalty for failure to acquire the missing capability is high under baseball arbitration (i.e., a payoff of zero or at best V_1)—leading to overinvestment in capability acquisition efforts relative to first best. However, overinvestment is not a concern if the cost of effort is sufficiently low—that is, when exerting maximum effort is first best. Given that the same effort and offer behavior are observed under baseball arbitration and dual-option contracts, they lead to identical levels of social welfare. The baseball arbitration contract is strictly superior to the dual-option and no–upfront contracting choices for high γ and low c. Baseball arbitration contracts perform better than dual option contracts with a high strike price because the mixed strategy that arises under partial implementation means that—unlike the case of a dual-option contract—there is a nonzero probability that some proposal will be made when both parties achieve only partial implementation and the project will then be taken forward by one party only. Baseball arbitration can outperform the no–upfront contract alternative because it induces both parties to exert effort; hence baseball arbitration yields an implementation hedge that is unavailable if a contract is not signed upfront. One disadvantage of baseball arbitration is overinvestment relative to socially optimal capability acquisition efforts, which destroys more value when c is high. Thus the second trade-off described at the end of Section 3.3 moves the innovator away from baseball arbitration when c is high: the cost of capability acquisition efforts is greater than the benefits from a hedge against failure and implementation uncertainties.

4.4. Reciprocal Option

Recall that the reciprocal option has two distinguishing characteristics: the option's strike price is not set ex ante, instead being stipulated at the time of offer; and the recipient of the offer can reciprocate it—that is, buy out the offering party at the offered strike price. This contract structure, too, is solved via backward induction.

Making the Offer and Determining the Price. The decision in the first step includes both whether (or not) to make an offer and at what price. Note that the offer decision is a simultaneous-move game. If both parties decide to make an offer, we randomly assign who moves first.

First, we study the case in which only one party is successful at acquiring the other's capability. In this case, it is easy to show that the successful party should make an offer with a strike price of $B = 0$—safe in the knowledge that the other party cannot reciprocate.

However, if both parties are successful then the agents will be strategic about whether or not to make an offer; the reason is that being in a position to reciprocate an offer is preferable to making an offer. The decision to offer and the amount of the offer are separable decisions. The strike price is set with reference to the offeror's anticipation of the offeree's reaction and does not depend on the former's own implementation level. If the offer's recipient is indifferent between accepting it or not, then we assume that it is accepted. The decision on whether or not to make an offer is the outcome of a strategic game that is summarized in Proposition 5.

PROPOSITION 5. *If each party has acquired the other's capability, then the optimal offer strike price is $B=\gamma V_2/2$ and the optimal offer strategies are as follows.*

1. *If $\gamma V_2 \le 2V_1$: An offer is made whenever $\Gamma=1$ and no offer is made otherwise.*
2. *If $\gamma V_2 > 2V_1$: An offer is made whenever $\Gamma=\gamma$; however, if $\Gamma=1$ then the parties play a mixed strategy whereby an offer is made with probability $\pi=\frac{\gamma V_2-2V_1}{V_2-2V_1}$.*

In case 1, the mechanics of the reciprocal option contract prevent product allocation to a single party if only partial implementation has been achieved; they also ensure that the product is not developed jointly if full implementation has been achieved by at least one party. In case 2, the two parties may end up developing jointly—despite each having achieved full implementation—because both parties would prefer to be the offeree (which would allow them to reciprocate and thus appropriate more value) than the offeror. Yet if both parties have attained full implementation and opted not to make an offer, then each is left with a payoff of V_1. This amount is strictly less than the strike price ($B=\gamma V_2/2$) and is also strictly less than the product value *minus* the strike price ($V_2-\gamma V_2/2$), which are the respective amounts garnered by an offeror and an offeree. Thus both parties, irrespective of their roles in the process, would be better off had an offer been made. The reluctance to make an offer is driven by the difference in revenue for offeror and offeree and so it declines as that difference decreases (i.e., as γ increases), per Proposition 5.

Choosing the Effort Level. In this step, the two parties choose their effort level to maximize their value while taking into account both the "offer game" they will be playing next and the other party's anticipated best-response effort level. We characterize the parties' respective efforts in Lemma 5.

LEMMA 5. *Under a reciprocal option contract, the optimal efforts are as follows.*

1. *If $\gamma V_2 > 2V_1$, then $p_R=q_R=\min\left\{1,\frac{4(V_2-2V_1)((1+\gamma)V_2-2V_1)}{(2+\gamma(1+\gamma))V_2^2-2(5+3\gamma)V_2V_1+16V_1^2-8c(V_2-2V_1)}\right\}$.*
2. *If $V_1<\gamma V_2<2V_1$, then $p_R=q_R=\min\left\{1,\frac{4((1+\gamma)V_2-2V_1)}{(1+4\gamma)V_2-10V_1+8c}\right\}$.*
3. *If $\gamma V_2<V_1$, then $p_R=q_R=\min\left\{1,\frac{4(V_2-V_1)}{V_2-2V_1+8c}\right\}$.*

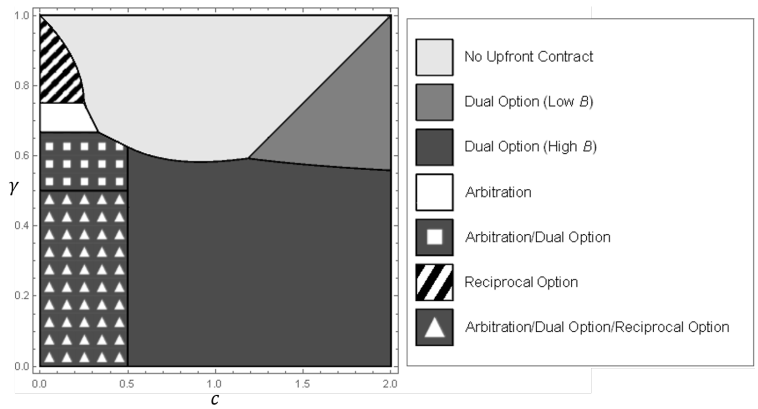

Figure 5 **Optimal contracting choice with dual option, baseball arbitration, and reciprocal option**

Proposition 6 gives the condition for which the reciprocal option contract is optimal.

PROPOSITION 6. *The reciprocal option contract is equivalent to the baseball arbitration and dual-option contracts for* $c \le \frac{V_2 - 2V_1}{4}$ *and* $\gamma \le \frac{2V_1}{V_2}$. *The reciprocal option contract dominates the other contract forms when* $\gamma \ge \gamma_4$ *and* $c \le \frac{(1-\gamma)(\gamma V_2 - 2V_1)V_2}{2(V_2 - 2V_1)}$.

Proposition 6 and Figure 5 illustrate that the innovator may prefer to use the reciprocal option when c is low and γ is either high or low (but not when γ takes intermediate values). If γ is low—and so the optimal action for the two parties under a reciprocal option contract is the pure strategy described in Proposition 5—then the reciprocal option, baseball arbitration, and the dual buyout–buyback with a high strike price are equivalent. All of these contracts induce maximum effort and, in each case, only a party that has implemented its new capability in full makes an offer or proposal that is accepted or exercises its option. We remark that these are the same effort levels and product allocation outcomes as when the central planner decides. Thus these three contracts achieve maximum social welfare when γ is low.

The advantages of the reciprocal option over not signing an upfront contract or signing a dual option contract are similar to the advantages of baseball arbitration (see the discussion in Section 4.3). If γ is high, and so the optimal action for the two parties is the mixed strategy described in Proposition 5, then the reciprocal option's two main disadvantages are minimized. One disadvantage of the reciprocal option contract is that, when only one party has acquired the other's capability (which is observable), the newly capable party can buy out the other at a strike price of zero. The possibility of this zero strike price is a severe penalty in the event of failure, and results in overinvestment relative to socially optimal efforts.[9] However, this problem is not an issue when

[9] This result contrasts with the holdup problem, where an agent's concerns about not being rewarded later—for an investment made today—leads to underinvestment. In our case, a similar concern leads to overinvestment because higher investment reduces the probability of no later reward.

the cost of effort is low because socially optimal efforts are $p=q=1$ to begin with. The reciprocal option's second disadvantage is due to the parties' strategic behavior when $\Gamma=1$. If both parties have achieved full implementation yet choose to refrain from making an offer, then they are left with a total payoff of $2V_1$. This amount is strictly less than V_2, which could have been earned by developing the product alone. Because the likelihood of not making an offer is decreasing in γ, this problem is minimized when γ is high. Therefore, the reciprocal option outperforms other contracts only in the high-γ area of Figure 5.

4.5. Reciprocal Option with a Price Floor

The relatively small region of optimality for the reciprocal option just described led us to explore whether one can improve on this innovative contract and thereby bring it into the mainstream. We pointed out that a major downside of the reciprocal option contract was that parties wary of receiving a zero offer will tend to overinvest in capability acquisition efforts. This tendency limits the reciprocal option's applicability to the low–effort cost region, where overinvestment is not an issue. We propose a simple modification that remedies this problem: a nonnegative lower bound s on the strike price to be set by the innovator when the contract is signed. A clear implication of this added degree of freedom is that the innovator cannot be worse off under this contract than under the reciprocal option *without* a price floor; after all, the innovator can still set the price floor to zero. Hence the question is whether this modification could lead to wider adoption of the reciprocal option contract. Once again, we solve the game using backward induction.

Making the Offer and Determining the Price. To ensure that the price floor is less than the strike price of the offer made when both parties are successful in acquiring the missing capability, we require that $s\le\gamma V_2/2$. This inequality implies that there is no change in the offer behavior when both parties are successful in acquiring the missing capability (see Proposition 5). If only one of the parties has acquired their previously missing capability, then that party makes an offer of s when $\Gamma V_2-s>V_1$. Thus an offer is always made when a newly acquired capability is implemented in full ($\Gamma=1$) but not necessarily when it is partially implemented ($\Gamma=\gamma$).

Choosing the Effort Level. In this step, the parties choose their effort level to maximize their value. When doing so, they account for the other party's anticipated best response and strategic behavior. Lemma 6 shows how efforts depend on the price floor, which is then optimized in Lemma 7.

Lemma 6. *Under a reciprocal option contract with a price floor, the optimal efforts are:*

1. *if* $\gamma V_2>2V_1,$ *then* $p_{\underline{R}}=q_{\underline{R}}=\min\left\{1,\frac{4(V_2-2V_1)((1+\gamma)V_2-2(s+V_1))}{16V_1^2-2(5+3\gamma)V_1V_2+(2+\gamma+\gamma^2)V_2^2+8c(V_2-2V_1)}\right\};$

2. *if* $V_1 < \gamma V_2 < 2V_1$ *and* $s < \gamma V_2 - V_1$, *then* $p_{\underline{R}} = q_{\underline{R}} = \min\left\{1, \frac{4(1+\gamma)V_2 - 8(s+V_1)}{8c+(1+4\gamma)V_2-10V_1}\right\}$;
3. *otherwise,* $p_{\underline{R}} = q_{\underline{R}} = \min\left\{1, \frac{4(V_2-V_1+s)}{V_2-2V_1+8c}\right\}$.

Setting the Price Floor for Symmetric Efforts. The price floor is set to optimize total value while respecting the proviso that it should be *lower* than the strike price of the reciprocal option ($s \le \gamma V_2/2$).

Lemma 7. *The optimal price floor for a reciprocal option is:*

1. *If* $\gamma V_2 > 2V_1$*:*
   (a) *If* $c \ge \frac{(2+\gamma(1+\gamma))V_2^2+16V_1^2-2(5+3\gamma)V_1V_2}{8(V_2-2V_1)}$*:* $s = \min\left\{\frac{\gamma V_2}{2}, \frac{(1+\gamma)V_2}{4} + \frac{4c((1+\gamma)V_2-4V_1)(V_2-2V_1)}{32(c-2V_1)V_1+8((5+3\gamma)V_1-2c)V_2-4(2+\gamma+\gamma^2)V_2^2)}\right\}$
   (b) *If* $c < \frac{(2+\gamma(1+\gamma))V_2^2+16V_1^2-2(5+3\gamma)V_1V_2}{8(V_2-2V_1)}$*:* $s = \min\left\{\frac{\gamma V_2}{2}, \frac{(1-\gamma)\gamma V_2^2+2(1+\gamma)V_1V_2-8V_1^2}{4(V_2-2V_1)}\right\}$
2. *If* $V_1 < \gamma V_2 \le 2V_1$*:* $s = \frac{\gamma V_2}{2}$
3. *If* $\gamma V_2 \le V_1$*:* $s = \frac{\gamma V_2}{2}$

The numerical results plotted in Figure 6 illustrate that the reciprocal option contract is now optimal in the region where γ and c are both high, where it can displace the dual-option contract with low strike price. Hence a lower bound on the strike price that can be offered eases each party's concern about being left empty-handed (should their efforts fail) and so allows them to reduce their efforts, bringing them closer to socially optimal levels. This outcome makes the reciprocal option with a price floor effective when c is high, or when excess efforts are more costly. In addition, the contract's reciprocity feature enables a better implementation hedge than does the dual-option contract with a low strike price. When one party has attained $\Gamma = \gamma$ and the other $\Gamma = 1$, the dual-option contract with a low strike price has an even chance of resulting in the party with $\Gamma = \gamma$ making the first offer and developing the product on its own. This allocation outcome, which is clearly suboptimal, would not occur under the reciprocal option contract. The reason is that, if

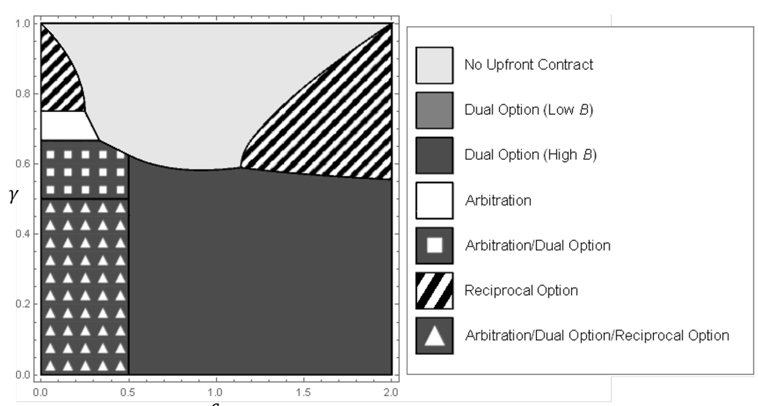

Figure 6 Optimal contracting choice with dual option, baseball arbitration, and reciprocal option with price floor

the party with $\Gamma = \gamma$ made a buyout offer, then the party with $\Gamma = 1$ would reciprocate—leaving the product in the hands of the more capable party. The trade-offs between the reciprocal option contract and the dual option contract with a high strike price remain the same as those described in Section 4.4. As a result, the former remains optimal in the high-γ region and the latter in the low-γ region.

4.6. Benefits of Mechanisms to Turn the Tables

We set out to identify which contractual forms could best accommodate dynamics in R&D alliances that arise because of the parties' efforts to attain new capabilities that reduce their interdependence. We found that two characteristics of traditional option contracts render them too static in the presence of dynamic capabilities: they specify a fixed strike price ex ante; and allocation is final when the option is exercised. In contrast, mechanisms to turn the tables—both baseball arbitration and reciprocal option contracts—offer two unique features: the *flexibility* to determine the price ex post and *reallocation* after a proposal or offer is made.

The value of the flexibility feature is observed in comparison with the dual buyout–buyback option with a high strike price. The high strike price makes it unprofitable for a party that only partially implements the other party's capability to exercise the option. If the best capability acquisition outcome is partial implementation and if the product would be more valuable in the hands of a single party, then inefficient joint development results. By not binding the offeror to a pre-determined strike price, both baseball arbitration and the reciprocal option contract enable parties to make buyout offers that vary as a function of their respective capability acquisition outcomes. Thus *the flexibility feature attenuates the inefficient joint development outcome.*

The reallocation feature's value is observed in comparison with the dual buyout–buyback option with a low strike price. A low strike price makes it profitable for a party who only partially implements the other party's capability to exercise the option even if the other party has implemented their acquired capability in full. When this occurs, the product ends up in the hands of the less capable party, leading to inefficient product allocation. Should an offer be made by a less capable party, both baseball arbitration and the reciprocal option contract make it possible for a more capable party receiving the offer to turn the tables and take the product in-house. Thus *the reallocation feature attenuates the inefficient product allocation outcome.* In effect, the reallocation feature acts as an information revelation mechanism, alleviating asymmetric information: a party that counterproposes or reciprocates must have implemented its newly acquired capability in full.

In sum, mechanisms to turn the tables incorporate flexibility and reallocation features that compensate for the two drawbacks of the dual buyout–buyback contract: inefficient joint development (when the strike price is high) and inefficient product allocation (when the strike price is low). Provided that these improvements outweigh the downsides due to strategic behavior under the baseball arbitration or reciprocal option contracts, mechanisms to turn the tables are beneficial.

5. Conclusions and Managerial Implications

The biopharmaceutical industry has witnessed a trend toward earlier-stage alliances. Long lead times to market mean that each party's capabilities will likely change during the course of an alliance. Although complementary capabilities are a chief driver of collaboration, either party that acquires the other's capability is in a position to bring the product to market on its own—with the benefits of avoiding agency and monitoring costs.

We have therefore explicitly modeled the efforts of each party to acquire the other's capability as well as their efforts to create value. Dynamic capabilities engender two types of uncertainties: about whether either party will, in fact, acquire the other's capability; and about how well a newly acquired capability will be implemented. We assessed the effectiveness of different contracts in this context. In particular, we surveyed dual option, baseball arbitration, and reciprocal option contracts and compared them to a benchmark of no upfront contracting. In different contexts, option contracts are known to enable better responses to the resolution of various uncertainties. Baseball arbitration and reciprocal option contracts are interesting yet understudied mechanisms that are employed in practice and could improve the response of firms to uncertainties. We focus on these latter two contract types because they share two relevant features: such contracts (i) allow either party to specify the price at which they offer to buy out the other party *at the time of the offer*, rather than when the contract is signed; and (ii) give the party receiving that offer the *right to turn the tables* and buy out the party that made the initial offer.

We found that the value of each contract depends on the difficulty of acquiring the other party's capability and also on the uncertainty associated with how well that capability will be implemented. Table 2 maps these two factors onto recommended contracts. The optimal contract aims to balance effort costs, uncertainties about capability acquisition and implementation, and inherent contractual inefficiencies. The relative importance of these concerns varies with the contracting environment. Not signing a contract upfront allows a party to avoid agency and monitoring costs, but efforts from both parties serve as a hedge against the uncertainties of capability acquisition and implementation.

Whenever implementation uncertainty is *high*, hedging against it naturally gains in significance and so contracting becomes more attractive. The dual option contract with a high strike price

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Difficulty of Acquiring Other Party's Capability</td></tr>
<tr><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td rowspan="3">Implementation Uncertainty</td><td rowspan="2">Low</td><td>Reciprocal Option</td><td rowspan="2">No Upfront Contract</td><td rowspan="2">Reciprocal Option with a Price Floor</td></tr>
<tr><td>Baseball Arbitration</td></tr>
<tr><td>High</td><td colspan="3">Dual Buyout–Buyback Option with a High Strike Price</td></tr>
</table>

Table 2 Innovator's Optimal Contract Choice

performs best regardless of how difficult it is to attain the other party's capability. The high strike price ensures that the option is exercised only with full implementation; otherwise, the parties continue jointly. This outcome is efficient when the value under partial implementation is low (i.e., implementation uncertainty is high). Note that in the lower left corner of Table 2, where implementation uncertainty is high and the difficulty of acquiring the other party's capability is low, we have shown different contract structures to be equivalent. Nevertheless, we display the dual option contract with a high strike price because it involves one less step—once a buyout is triggered—and so is easier to implement.

If implementation uncertainty is *low* and if capability acquisition is less costly, then it makes sense for both parties to invest in acquiring their missing capability despite the lower value of the implementation hedge. Under these circumstances, baseball arbitration and reciprocal option contracts outperform a dual option contract with high strike price because of their better allocation, and no upfront contracting because of their implementation hedge. We also observe that inefficiencies resulting from the two forms of strategic behavior—no offer by either party and a zero offer by one party—are minimal or eliminated in this region. Which of baseball arbitration or reciprocal option contracts prevails depends on the relative value loss due to the first form of strategic behavior. Under baseball arbitration, this occurs for parties who have only partially implemented the other's capability. Hence the loss is of lower magnitude for higher implementation uncertainty, in which case baseball arbitration is preferred. Under a reciprocal option, strategic behavior is exhibited by parties who have fully implemented the other party's capability. Such behavior occurs less frequently if the implementation uncertainty is low. Hence there is less of a loss when implementation is less uncertain, and a reciprocal option is preferred.

As effort costs increase, a contract that induces both parties to invest heavily in capability acquisition is no longer beneficial. Yet a social planner would still be justified in encouraging just one party to incur a high acquisition cost—especially when implementation uncertainty (and hence the benefit from an implementation hedge) is low. It follows that an innovator in these circumstance should refrain from signing an upfront contract but, at the same time, should work hard to acquire her missing capability.

Finally, as it becomes even more difficult to acquire the other party's capability, the innovator's high effort in the absence of upfront contracting becomes too costly; then contracting is preferred for its ability to create, at reasonable cost, a hedge against both capability acquisition uncertainty and implementation uncertainty. Here the reciprocal option with a price floor is preferred because it maintains allocation efficiency and also, thanks to the price floor, prevents overinvestment from the parties that the second form of strategic behavior (i.e., a zero offer) would have induced.

Our analysis also allowed us to uncover exactly why baseball arbitration and the innovative reciprocal option work. Although the dual option contract likewise allows both parties to exercise the option, one must bear in mind the advantages of contracts that enable parties to turn the tables. First, the flexibility of setting the buyout price ex post allows a party to make a buyout offer at a strike price that reflects the capability acquisition outcomes. This feature alleviates the inefficient joint development problem, which is a drawback of the dual option contract with a *high* strike price. Second, the reallocation feature ensures that a more capable party will always reciprocate a less capable party's offer; this alleviates the inefficient allocation outcome, which is a drawback of the dual option contract with a *low* strike price. It is this capacity to address both of these inefficiencies that render mechanisms to turn the tables valuable in settings where their own (unique) drawbacks are minimal.

It is important to compare our findings to observations from practice. The model presented here indicates that standard option contracts are optimal over a large range of parameters, which is consistent with their wide adoption in practice. Our model shows also that there are limited circumstances under which the reciprocal option should be preferred over other contracts; this finding is consistent with the observation that reciprocal option contracts are seldom used in practice. Nevertheless, we offer a modification to that contract—adding a price floor—that would minimize its downsides and make it much more attractive. In this sense, our results are also prescriptive.

The region where baseball arbitration should be preferred is similarly limited in our model. This result is at odds with the widespread use of baseball arbitration clauses in biopharmaceutical agreements. We believe there are several reasons for the discrepancy. First, we model only disputes related to one party's intention to buy out the other, yet baseball arbitration clauses apply to a broader set of disputes. For example, the agreement between Cydex and Spectrum Pharmaceuticals (detailed in the eCompanion) states that "any and all disputes or controversies arising out of or relating to this Agreement shall be exclusively and finally resolved by binding arbitration ... on the basis of 'baseball arbitration' principles". Second, arbitration proceedings and arbitral awards are confidential, a feature that many firms find attractive (Bennett 2002, Boyd 2003). Third, because of provisions in the United Nations Convention on the Recognition and Enforcement of Foreign Arbitral Awards, such awards are easier to enforce internationally than are court judgments. In light of our findings and other research into litigation (Ryall and Sampson 2017), future work could well consider comparing the use of litigation to that of arbitration.

Our paper contributes to the literature in a number of ways. First, we introduce a model that explicitly accounts for efforts by parties to attain missing capabilities. Second, we examine baseball arbitration and reciprocal option contracts which are novel to the R&D licensing literature. Third, the relatively limited circumstances under which the reciprocal option is beneficial prompted us to modify it in a way that would substantially increase its applicability. By introducing and setting an optimal lower bound on the exercise price that the two parties can offer each other, we enable the innovator to mitigate the overinvestment problem that arises without such a lower bound. Incorporating this modification substantially increases the applicability of the reciprocal option contract. We focus on improving the reciprocal option—rather than baseball arbitration—contract for two reasons: (i) the practitioners we interviewed stressed that the reciprocal option contract seems to "automate" the baseball arbitration process common in biopharmaceutical R&D licenses; and (ii) arbitration is both time-consuming and costly. It follows that a well-designed reciprocal option contract has the potential to reduce the need for arbitration while maintaining its benefits. These insights provide guidance to managers about how, in the face of dynamic capabilities, they should structure and execute contracts for early-stage partnerships.

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