Contract Renegotiation and Options in Agency Problems

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This article discusses the ability of an agent and a principal to achieve the first-best outcome when the agent invests in an asset that has greater value if owned by the principal than by the agent. When contracts can be renegotiated, a well-known danger is that the principal can hold up the agent, undermining the agent's investment incentives. We begin by identifying a countervailing effect: Investment by the agent can increase his value for the asset, thus improving his bargaining position in renegotiation. We show that option contracts will achieve the first best whenever his threat-point effect dominates the holdup effect. Otherwise, achieving the first best is difficult and, in many cases, impossible.

1. Introduction

We analyze agency problems with renegotiation, asking when it is possible to give an agent efficient incentives to work on an asset or project that a principal will use or market. Following the incomplete contracts literature, we assume that the principal observes the agent's action, but cannot prove what it was in court. Courts can verify only (1) payments between the parties, (2) possession (ownership) of the asset or project, and (3) contractually binding statements such as offer, accep-

This article contains material that originally appeared in our earlier working paper, "Contract Renegotiation in Agency Problems," which we have subsequently divided into this article and Edlin and Hermalin (2000). The authors thank Yeon-Koo Che, Preston McAfee, Paul Milgrom, Stefan Reichelstein, Bill Rogerson, Alan Schwartz, Ilya Segal, Chris Shannon, Lars Stole, and participants at the Murray S. Johnson Economics Conference, University of Texas, the 1997 ALEA meetings, the 1997 NBER Summer Institute Program on Law & Economics, the 1997 Industrial Organization Conference at the University of British Columbia, the 1998 Contract Law Conference at Tel Aviv University, a Cornell University workshop, a University of Maryland workshop, and an Olin School workshop for their comments and suggestions. Edlin thanks the Sloan Foundation for a Faculty Research Fellowship and Georgetown Law Center for a Fellowship in Law and Economics. Hermalin acknowledges support from the NSF, SBR-9616675, and the Willis H. Booth Chair in Banking & Finance. The authors also thank Eric Emch for research assistance.

tance, or the exercise of an option. Like Demski and Sappington (1991) and Hermalin and Katz (1991), we consider models with a usable time period between the agent's investment and the realization of uncertainty. This timing eliminates the usual trade-off in the principal-agent literature between risk sharing and incentives because "the store" can be sold to the agent before he invests and repurchased by the risk-neutral principal before uncertainty is realized. Nonetheless, we find that inefficiency will often persist, contrary to the conclusions of the earlier work by Demski and Sappington (1991) and Bernheim and Whinston (1998), and the contemporaneous work by Nöldeke and Schmidt (1998). In particular, if renegotiation involves surplus sharing, as it often will, then the inefficiency can be inescapable.

As an example, consider the problem that Pixar and Disney faced when they collaborated to produce the animated feature *Toy Story*. Each party brought unique talents to the table: Pixar had the 3-D animation technology and Disney had the distribution and marketing expertise for animated films.[1] Prior to release, Disney could observe the quality of the film Pixar produced, but quality is sufficiently amorphous that it would be difficult, if not impossible, for it to be described in a contract or demonstrated in court unambiguously. Giving Pixar appropriate incentives would, then, seem problematic. If Disney commits to buy at a fixed price, then Pixar, acting opportunistically, has no incentive to work hard for Disney.[2] On the other hand, negotiating the price after Pixar makes the film is also problematic: Pixar may hesitate to work hard because Disney, bargaining opportunistically, can capture some of the value Pixar creates [see Williamson (1985) for more on such holdups].

But what about a compromise in which the parties fix a price initially, but give Disney the option to cancel the deal? Buying the film at that price will only be attractive to Disney if Pixar makes a sufficiently good film. The question then is whether Disney's threat not to purchase the film will induce Pixar to work hard? Demski and Sappington (1991), Bernheim and Whinston (1998), and Nöldeke and Schmidt (1998) all argue that it will: Pixar and Disney will both have efficient incentives under a contract that gives ownership of the film to Pixar, but gives Disney an option to purchase it at a price that equals the film's final value to Disney assuming Pixar exerts optimal effort. Absent renegotiation, this contract is efficient, but, as we show, Disney has an incentive to let its option expire and subsequently renegotiate a lower price for the film. Even if the parties make the option nonexpiring, renegotiation

1. According to Pixar's CFO, the animated-film business is essentially a Disney monopoly. Source: "Lost Toys," *The Economist*, vol. 342, no. 7999 (Jan. 11, 1997), p. 58.

2. Pixar still has some incentive to develop the technology for other films, but not as much as if it had the additional incentive to work hard for Disney.

is still a relevant threat: Disney has an incentive to delay investing in promotion and distribution until it can renegotiate a better deal.[3] Hence these option contracts ultimately provide little or no protection from the holdup problem we observed initially. The protection from holdup claimed by these authors is thus not a property of option contracts. Rather, protection is afforded by not allowing renegotiation (Demski and Sappington, 1991) or by making strong assumptions that effectively guarantee the agent has take-it-or-leave-it bargaining power ex post.

Under an option scheme, and without renegotiation, giving the agent initial ownership of the asset provides the agent with incentives to work efficiently, because if the agent shirks, then the principal will let her option expire and leave the project with the agent. But when renegotiation is a relevant threat, then even if the agent takes the appropriate action, an opportunistic principal will let her option expire or delay investing in order to bargain for a lower price in renegotiation. Typically we would expect the principal to capture a share of the renegotiation surplus, so that the agent does not capture the full marginal contribution of his efforts to the principal's value. This holdup effect undermines the agent's incentives to work. Yet there is a second effect: The agent's effort will strengthen his bargaining position, since if bargaining breaks down and he winds up with the project, his effort would give the project greater value.[4] We find that a suitably chosen option contract will provide first-best incentives when this second effect, the threat-point effect, dominates the holdup effect. In this case, it is the threat of renegotiation that gives the agent incentives to work hard and, ironically, the role of an option is now to guard against *over*investment by the agent. When the holdup effect dominates the threat-point effect, on the other hand, we show that no option contract is efficient for any strictly monotonic sharing rule.[5]

When the principal and agent's efforts are substitutes, the threat-point effect tends to dominate, because the agent's effort has higher marginal contribution when he owns the project that when the principal owns the

3. Nöldeke and Schmidt (1998) suggested the nonexpiring option idea in response to one of our drafts. Having a nonexpiring option only avoids renegotiation if there is a rock solid date when the principal must invest, after which the asset value (or investment value) becomes zero. Otherwise, if the decline in value with delay is at all gradual (or 0), then delay will be attractive, because it will take the option "out of the money" and force renegotiation.

4. This effect can be quite large. For example, according to "Woody and Buzz: The Untold Story" (*New York Times*, February 24, 1997), Disney tripled its price to Pixar on future pictures out of concern that Pixar would break with Disney and take its now-proven technology to Warner Brothers or another studio.

5. We say that two parties have a monotonic sharing rule if, when they bargain over a pot of money, their shares each increase with the amount in the pot. See Edlin and Reichelstein (1996).

project and contributes her own effort. Conversely, the holdup effect dominates when their efforts are complements.[6] We can interpret this issue of complementary or substitute efforts in terms of specific versus general investments. Since we assume the asset is more valuable to the principal than to the agent, investments must be specific *on average*. When, however, the agent's investment substitutes for the principal's on the margin, then his investment is more general than specific *on the margin*. The case of complementarity efforts can be interpreted as the agent's investment being more specific than general on the margin. These observations imply that what matters for efficiency is not whether investments are general or specific on average, but whether they are general or specific on the margin. We also find that the threat-point effect will tend to be larger if effort reduces the risk premium (the difference between the expected and certainty equivalent value to the agent of keeping the asset), but smaller if effort increases the risk premium.

The possibility that there is no efficient option contract leads us to consider general mechanisms. With a risk-neutral agent, we show that the first best is implementable if and only if the threat-point effect dominates the holdup effect; and thus if and only if it is implementable via option contracts. If the first best is unattainable with a risk-neutral agent, then the second-best contract proves to be "no contract" (equivalently, an option contract with an infinite strike price). On the other hand, for a risk-averse agent, it is possible that a general mechanism could exploit his risk aversion to overcome the holdup effect even when the threat-point effect is weak; though this possibility is by no means guaranteed.

Our work is related to the large literature on trading mechanisms (see, e.g., Chung, 1991; Rogerson, 1992; Hermalin and Katz, 1993; Aghion et al., 1994; Nöldeke and Schmidt, 1995; Edlin and Reichelstein, 1996; among others). There are, however, important differences. The most obvious of which is that we allow for a risk-averse agent, whereas

6. Complementarity and substitutability also play a role in Bernheim and Whinston (1998). In our article, these concepts are defined with respect to the production process, a primitive. In contrast, Bernheim and Whinston speak of *strategic* complements and substitutes. Since the contract helps to fix the strategy spaces, whether actions are strategic complements or substitutes depends on the contract in place and may differ between principal and agent. For instance, if the contract allows the principal to choose the probability that she gets the asset ("quantity") and the agent to choose quality, then their actions are typically strategic complements for the principal; however, if the asset's value to the agent is increasing in quality, then their actions will be strategic substitutes for the agent.

Complementarity and substitutability are also an issue in the control literature (see, e.g., Grossman and Hart, 1986; Chiu, 1998). Unlike here, where efficiency dictates that ownership (control) always be given to the principal in the end, this literature focuses on who should be given control.

this literature assumes risk neutrality. Although risk neutrality is a reasonable assumption in those contexts, as well as some we consider here, risk aversion is a central ingredient in many other agency problems. A more fundamental difference is that the contracting and incentive problem that these authors study arises because they assume it is impossible to write a contract that results in efficient trade in all contingencies. In contrast, in our model "trade" (the principal owning the asset at the end) is always efficient, but a contract specifying this outcome provides insufficient incentives for the agent. This difference arises because this literature models the agent's investment as affecting only his cost of production and trade, while we model the agent's investment as affecting the value of the asset. Hence, because the principal owns the asset in the end, the agent's investment affects the principal's valuation. This feature makes investment "cooperative" in the sense of MacLeod and Malcomson (1993), Che and Chung (1996), and Che and Hausch (1999).[7] The critical analytic difference between our model and theirs is that we consider the possibility that the agent's effort has value even if the agent retains the project—the "no trade" case in their models. This possibility creates the threat-point effect we identified above, which can support efficient contracts when the parties' efforts are substitutes. On the other hand, our result that complementary efforts can cause inefficiency agrees with Che and Hausch (1999). For more on the subtle mappings between trade and agency models, see Edlin et al. (1998).

In a general sense, our attitude toward renegotiation is more pessimistic than Bernheim and Whinston's (1998), Nöldeke and Schmidt's (1998), and (implicitly) Demski and Sappington's (1991)—we are less sanguine about the parties prospects to contractually commit themselves not to renegotiate or, equivalently, to give all renegotiation power to one party. We detail the reasons for this in Sections 3 and 5. We argue that assuming the agent has such bargaining powers is dubious in many cases and would directly eliminate the very holdup problem that motivates this literature. The specific way that Nöldeke and Schmidt allocate bargaining power violates the outside option principle and would not work in many circumstances.

The next section lays out our model. In Section 3, we consider option contracts and renegotiation. As we again note, option contracts do not always achieve the first best. This leads us, in Section 4, to consider general mechanisms. In Section 5, we contrast the manner in which we've introduced renegotiation into the contracting problem with the approaches taken by others. We conclude in Section 6. As a rule, proofs can be found in the appendix.

7. We thank Bentley MacLeod, Jim Malcomson, Bill Rogerson, and Ilya Segal, each of whom independently pointed this connection out to us.

2. Model

Our model is similar to one posed by Demski and Sappington (1991). Figure 1 provides a timeline.

A principal, who owns a transferrable asset (e.g., patent, store, or movie idea) hires an agent. The agent undertakes an action $a \in [0, \infty)$. The principal observes this action, but it is not verifiable, so that contracts cannot be directly contingent on it. After observing the agent's action, the principal takes an action $b \in [0, \infty)$. These actions affect the asset's return, $r \in [\underline{r}, \infty)$, in a stochastic manner. Specifically, assume that the *density* over r conditional on a and b, $f(r \mid a, b)$, is increasing in a and b in the sense of first-degree stochastic dominance; that is, for all r, all $a \geq a'$ and $b \geq b'$,

$$\int_{\underline{r}}^{r} f(z \mid a, b)\, dz \leq \int_{\underline{r}}^{r} f(z \mid a', b')\, dz.$$

Assume that $f(r \mid \cdot, b)$ and $f(r \mid a, \cdot)$ are both differentiable functions for all r, a, and b. We denote the expected return conditional on a and b as

$$R(a, b) = \int_{\underline{r}}^{\infty} r f(r \mid a, b)\, dr.$$

The principal is risk neutral and her utility equals $y - b$, where y is her income. Let her value of the asset, conditional on the agent's action a, be

$$V(a) \equiv \max_{b \in [0, \infty)} R(a, b) - b.$$

We assume that $V(a)$ is finite for all a and we observe, by the envelope theorem, that $V'(a) = \partial R / \partial a \geq 0$.

The agent's utility is $u(w) - a$, where w is his income. Assume that $u(\cdot)$ is strictly increasing, twice differentiable, and at least weakly concave (i.e., the agent is not risk loving).

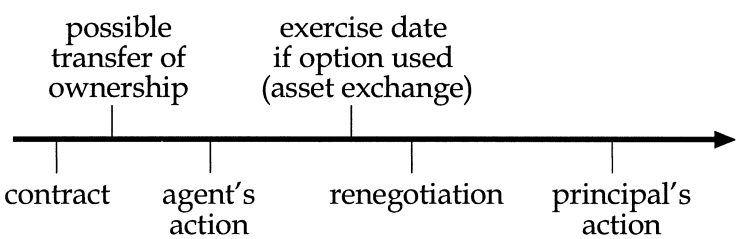

Figure 1. Timeline.

The initial bargaining game between the principal and agent, which we do not model yields the agent an expected equilibrium level of utility that we normalize to 0. We can therefore model the contract design problem as maximizing the principal's expected utility subject to the agent's expected utility being zero. Hence, in a first-best world, the problem is

$$\max_{p,\, a \in [0,\infty)} V(a) - p$$
$$\text{subject to } u(p) - a = 0. \tag{1}$$

We assume a *unique* interior solution to this program, a^*. The first-order condition with respect to a is

$$V'(a^*) = \frac{1}{u'\left[u^{-1}(a^*)\right]}. \tag{2}$$

To ensure that the agent can be given sufficient incentives, we assume

Assumption 1. The domain of $u(\cdot)$ includes $(\underline{r} + u^{-1}(a^*) - V(a^*), \infty)$.

3. Option Contracts and Renegotiation

Consider an option contract (p_1, p_2). Upon acceptance of the contract, the principal transfers ownership of the asset to the agent together with p_1 (a negative p_1 is a payment to the principal).[8] Observe that p_1 is an unconditional transfer. After the agent has chosen his action, the principal has the option to buy back the improved asset at price p_2. If the principal declines to exercise her option, then the agent retains ownership. After the principal decides whether to exercise her option, she chooses her effort. The owner of the asset receives r.

Setting the exercise date before the principal invests reverses the timing in Demski and Sappington (1991). In a model without renegotiation, the order of these two events is irrelevant. It does, however, matter with renegotiation. We favor our timing because, as we discuss in Section 5, with the other timing the principal has an incentive to delay investing until *after* the exercise decision (i.e., *endogenously* follow our timing).

We will first consider the case where renegotiation is not possible and then analyze the effects of renegotiation. Similar to what Demski and

8. If the agent has initial ownership, he maintains ownership at this stage.

Sappington (1991) find, we get the following result when renegotiation is *not* feasible.

Proposition 1. If renegotiation is infeasible, then an option contract with

$$p_1 = u^{-1}(a^*) - V(a^*); \quad \textit{and}$$
$$p_2 = V(a^*)$$

implements the first best.

Proof. The principal will exercise her option (given *no* renegotiation) if and only if $V(a) \geq p_2 = V(a^*)$; that is, if and only if $a \geq a^*$. Hence if the agent expends $a \geq a^*$ in effort, the principal will exercise her option and she will end up with the asset as efficiency requires. The agent's utility from choosing $a \geq a^*$ is thus

$$u(p_1 + p_2) - a.$$

It follows then that the agent would never choose $a > a^*$. By construction,

$$u(p_1 + p_2) - a^* = 0.$$

If the agent chooses $a < a^*$, then the principal will not exercise her option. In this case the principal's payoff is

$$-p_1 = V(a^*) - u^{-1}(a^*);$$

that is, her payoff equals the maximum total surplus [see Program (1)]. But this means that the agent's utility must therefore be negative if $a < a^*$: Since the agent has not supplied first-best effort, realized total surplus is less than maximum total surplus. Clearly then the agent would do better to choose $a = a^*$. ■

Proposition 1, like Demski and Sappington's analysis, does not consider, however, the possibility that the agent and principal renegotiate if the principal does not exercise her option.[9]

9. Since there is no renegotiation in Demski and Sappington's analysis, it doesn't matter whether the principal invests (chooses b) before or after exercising the option. That is, Proposition 1 is not dependent on when we assume the principal invests.

To use our example of Pixar and Disney, imagine that Pixar has already made the film and Disney has an option to purchase it. The exercise price is set so that after Disney pays it and invests in distribution and promotion, Disney expects to break even. Pixar, on the other hand, is much better off if Disney buys at that price than if Pixar is left to own and market the film on its own. We suspect that Disney will let its option expire and negotiate to buy the film at a lower price. Likewise, consider a publisher who has set the option price to publish an author's book so high that the publisher breaks even. The publisher will be sorely tempted to commence renegotiation once the book is written, but before publication.

If the principal lets her option expire, the agent will own the asset. If no sale or other contract is thereafter arranged, the principal will choose $b = 0$. The threat point in renegotiation (whether renegotiation to a sale or to another contract) is therefore the certainty equivalent payoff to the agent *for the asset*: that is,

$$CE(a, p_1) \equiv u^{-1}\left(\int_{\underline{r}}^{\infty} u(r + p_1) f(r \mid a, 0)\, dr\right) - p_1.$$

We also assume that the agent is risk averse or the principal's effort is valuable or both. Consequently,[10]

$$V(a) > CE(a, p_1). \tag{3}$$

Hence the principal must eventually own the asset if the first best is to be attained; that is, having the agent own the asset at the end is a strictly Pareto-dominated outcome. Since $V(a) > CE(a, p_1)$, there are gains from renegotiating and assigning ownership to the principal. We presume therefore that the principal will end up buying the asset. In doing so, she and the agent must agree to a division of the *renegotiation surplus*,

$$S(a, p_1) \equiv V(a) - CE(a, p_1).$$

We see no reason to assume that one of the parties captures all this surplus; more likely, it will be split between them. Following Edlin and Reichelstein (1996), we remain agnostic about the extensive form of this bargaining game. Rather, like them, we assume that the parties follow

10. *Proof*. $CE(a, p_1) \leq R(a, 0) \leq V(a)$, with one inequality strict if the agent is risk averse (certainty equivalent payoff less than expected payoff) or the principal's effort is productive ($V(a) > R(a, 0)$).

an *efficient monotonic sharing rule*:[11] that is, the agent and principal split the renegotiation surplus according to differentiable rules, $\sigma_A : \mathbb{R} \to \mathbb{R}_+$ and $\sigma_P : \mathbb{R} \to \mathbb{R}_+$ satisfying[12]

A. (efficiency) $\sigma_A(S) + \sigma_P(S) \equiv S$; and either
B. (weak monotonicity) $\sigma_A'(\cdot) \geq 0$, $\sigma_P'(\cdot) \geq 0$; or
B′. (strict monotonicity) $\sigma_A'(\cdot) > 0$, $\sigma_P'(\cdot) > 0$.

Constant-shares bargaining (i.e., $\sigma_A(S) = \beta S$ and $\sigma_P(S) = (1 - \beta)S$) is a special case of a monotonic sharing rule.

The principal's payment to the agent after renegotiation will be

$$p(a, p_1) \equiv \sigma_A[S(a, p_1)] + CE(a, p_1).$$

The principal will therefore exercise her option if $p_2 \leq p(a, p_1)$. Otherwise she will let it expire and renegotiate.

Demski and Sappington's approach is problematic when the agent does not have the power to make take-it-or-leave-it offers when renegotiating:

Proposition 2. The equilibrium of Proposition 1 is *not* robust to renegotiation unless the agent has all the bargaining power when he chooses the first-best action.

Proof. Consider the contract in which $p_2 = V(a^*)$. Suppose the agent chooses a^*, as in the equilibrium of Proposition 1. Observe

$$p(a^*, p_1) = \sigma_A[S(a^*, p_1)] + CE(a^*, p_1) \leq V(a^*) = p_2.$$

It follows that $p(a^*, p_1) < p_2$ unless $\sigma_A[S(a^*, p_1)] = S(a^*, p_1)$. If the agent does not have all the bargaining power, the principal will let her option expire rather than exercise it as required by the Proposition 1 equilibrium. ■

Remark 1. Since $\sigma_A(0) = 0$,

$$\sigma_A[S(a^*, \hat{p}_1)] = \int_0^{S(a^*, \hat{p}_1)} \sigma_A'(z)\, dz.$$

Consequently, Proposition 2 can be rewritten as: The Proposition 1 equilibrium is *not* robust to renegotiation unless the agent gets 100%

11. Appendix A of Edlin and Reichelstein (1996) contains an explicit extensive-form bargaining game in which the equilibrium solution has surplus split monotonically.

12. Monotonicity implies that $\sigma_A(\cdot)$ is differentiable almost everywhere. This is sufficient for the analysis that follows, but assuming differentiability everywhere simplifies the proofs.

of the marginal surplus for almost every level of surplus less than $S(a^*, \hat{p}_1)$ (i.e., unless $\sigma_A'(z) = 1$ for almost every z so $\int_0^{S(a^*, \hat{p}_1)} \sigma_A'(z)\, dz = S(a^*, \hat{p}_1)$).

Remark 2. Proposition 2 stands in stark contrast to Bernheim and Whinston's (1998) model, in which the Proposition 1 contract will achieve the first best (and won't be renegotiated along the equilibrium path) when the *principal* has all the bargaining power. Bernheim and Whinston's result depends on their assumption that renegotiation can only occur *before* the principal decides whether to exercise her option and *not* after.[13]

In a world without renegotiation, the principal is indifferent between exercising her option and letting it expire when $p_2 = V(a)$. With renegotiation, she gets some of the surplus from renegotiating an expired option contract (provided $\sigma_P[S(a, p_1)] > 0$), so that she prefers renegotiating to exercising her option. Consequently the principal can be expected to hold up the agent.

Holdup means that the agent cannot capture the full marginal contribution of his effort to the principal's value $V'(a)$, and this reduces the agent's investment incentives. It turns out, however, that even though holdup is unavoidable, it does not necessarily cause underinvestment. Offsetting the holdup effect is the threat-point effect: investment strengthens the agent's bargaining position by increasing the value of the asset if the agent retains it. If this threat-point effect is sufficiently large, it will dominate the holdup effect, and an efficient option contract can exist with renegotiation. If the holdup effect dominates, then an efficient option contract does not exist. Mathematically, for monotonic sharing, the condition that the threat-point effect dominates can be expressed as

$$\frac{\partial CE(a^*, p_1)}{\partial a} \geq V'(a^*) \tag{4}$$

13. Bernheim and Whinston consider option contracts in their Example 1. There are some differences between their model and ours—specifically, their principal makes no investment, quantities are continuous, and there is no uncertainty—but their analysis can be readily translated to our model. Their model of renegotiation (see their Section 4.4) assumes, unlike ours, that any renegotiation occurs prior to the principal's option-exercise decision and that this decision is irreversible—there is no subsequent chance for the principal to obtain ownership if she lets her option expire. Consequently, if $a = a^*$, then the principal cannot credibly threaten *not* to exercise an option with a strike price of $V(a^*)$. Renegotiation is thus irrelevant, so the first best is attainable using the Proposition 1 contract.

for p_1 solving[14]

$$u^{-1}(a^*) = p(a^*, p_1) + p_1. \tag{5}$$

That is, the threat-point effect dominates if the marginal impact of the agent's action increases his value for the asset (adjusted for risk) more than it increases the social (principal's) value for the asset. Since

$$\frac{\partial p(a, p_1)}{\partial a} = \sigma_A'[S(a, p_1)]V'(a^*) + \left(1 - \sigma_A'[S(a, p_1)]\right)\frac{\partial CE(a, p_1)}{\partial a}, \tag{6}$$

Condition (4) implies

$$\frac{\partial p(a^*, p_1)}{\partial a} \in \left(V'(a^*), \frac{\partial CE(a^*, p_1)}{\partial a}\right) \tag{7}$$

for *strictly* monotonic sharing. Hence, when the threat-point effect dominates, the agent's action increases his payment more than it increases the principal's marginal value for the asset. So even though the principal is capturing some of the increased value on the margin, it is still possible to given the agent sufficient incentives. If Condition (4)

14. To see that a p_1 solving Equation (5) exists, observe that the right-hand side of Equation (5) is continuous in p_1 under the assumptions on $\sigma_A(\cdot)$ and $u(\cdot)$. Moreover, the right-hand side of Equation (5) is bounded between $CE(a^*, p_1) + p_1$ and $V(a^*) + p_1$. The upper bound equals $u^{-1}(a^*)$ if

$$p_1 = u^{-1}(a^*) - V(a^*)$$

(recall, from Assumption 1, that

$$r + u^{-1}(a^*) - V(a^*)$$

is in the domain of $u(\cdot)$ for all possible r). We can conclude therefore that a p_1 solving Equation (5) must exist if we can show the lower bound goes to $+\infty$ as $p_1 \to +\infty$. To see that the lower bound indeed does so, note that

$$\int_{\underline{r}}^{\infty} u(r + p_1) f(r \mid a, 0)\, dr \geq u(\underline{r} + p_1)$$

for all p_1. Since $u^{-1}(\cdot)$ is increasing, we have

$$p_1 + CE(a, p_1) \geq \underline{r} + p_1$$

for all p_1. The result follows.

fails, then

$$\frac{\partial p(a^*, p_1)}{\partial a} \in \left(\frac{\partial CE(a^*, p_1)}{\partial a}, V'(a^*) \right) \tag{8}$$

for strictly monotonic sharing; consequently, sufficient incentives are no longer possible. The following proposition verifies that Condition (4) is necessary for an efficient option contract to exist under strictly monotonic bargaining.

Proposition 3. Assume that Condition (4) fails to hold for any p_1 solving Equation (5) and that renegotiation follows a strictly monotonic sharing rule. Then no option contract (p_1, p_2) is efficient.[15]

In contrast, an efficient contract will exist for monotonic sharing rules if Condition (4) holds and the first-order approach is valid. The first-order approach is valid if $u(p(a, p_1^*) + p_1^*) - a$ is *ideally* quasi-concave, where:

Definition 1. A differentiable function $f : \mathbb{R} \to \mathbb{R}$ is *ideally* quasi-concave if it is quasi-concave and if for any x^* such that $f'(x^*) = 0$, $f'(x) \cdot (x^* - x) > 0$ for all $x \neq x^*$ (note for an ideally quasi-concave function there can be at most one x^* such that $f'(x^*) = 0$).[16]

Proposition 4. Assume either that Condition (4) holds for some p_1^* solving Equation (5) and that sharing is monotonic; or that the agent receives 100% of the surplus on the margin when $a = a^*$ and $p_1 = p_1^*$. Then an efficient option contract exists provided that $u(p(a, p_1^*) + p_1^*) - a$ is ideally quasi-concave in a.

Note that the option price, $p(a^*, p_1^*)$, is less in Proposition 4 than in Proposition 1 (i.e., $p(a^*, p_1^*) \leq V(a^*)$). With renegotiation, the principal must be indifferent between exercising her option and taking possession through renegotiation, while in Proposition 1 she must be indifferent between exercising and foregoing possession. Unless $\sigma_A[S(a^*, p_1^*)] = S(a^*, p_1^*)$—which entails $\sigma_A'(z) = 1$ for almost every $z \in [0, S(a^*, p_1^*)]$ (see Remark 1 above)—taking possession through renegotiation is strictly preferable to foregoing possession altogether. Consequently the price must be lower than in Proposition 1 to account for renegotiation.

Another way to put this is that under the original Demski–Sappington contract, the principal's option is out of the money once renegotiation is considered: As we've shown, she would do better to let it expire

15. This result extends to *weakly* monotonic sharing rules provided $\sigma_A'[S(a^*, p_1)] < 1$.

16. Restricting attention to differentiable functions, the set of strictly concave functions is a proper subset of the set of ideally quasi-concave functions, which itself is a subset of the set of strictly quasi-concave functions.

and renegotiate the price than to exercise her option. In this light, Proposition 1 rests on the implicit assumption that the principal will exercise an out-of-the-money option.

In equilibrium in our model, the principal's option thus must have nonnegative value. On the other hand, it can't have positive value. If it has positive value, then the agent has invested more than necessary to induce exercise. From Demski and Sappington's original analysis, we know that won't happen in equilibrium. Hence, on the equilibrium path, the option must have precisely zero value.

If, as we've argued, the option must have zero value in equilibrium, one could ask why use an option at all? The principal answer is it guards against undesirable out-of-equilibrium behavior. In particular, the purpose of giving the principal an option is to protect her against overexertion by the agent: The case where an efficient contract exists is one where, without any contract, the threat-point effect is so strong that the agent would choose $a \geq a^*$. The principal's option thus serves to keep the agent from engaging in inefficient, rent-seeking behavior. Put somewhat differently, the role of the option with renegotiation is not to induce effort, but to prevent too much effort.[17]

To explore the significance of Condition (4) more readily, let the agent be risk neutral. Then $R(a, 0)$, the expected return to the asset if the principal supplies no effort *equals* the agent's certainty equivalent value. It follows that Condition (4) holds if

$$\frac{\partial^2 R(a^*, 0)}{\partial a \, \partial b} \leq 0; \tag{9}$$

that is, if the agent's and principal's actions are (weakly) substitutable on the relevant margin. On the other hand, if the agent's and principal's actions are complementary on the relevant margin, so that

$$\frac{\partial^2 R(a^*, 0)}{\partial a \, \partial b} > 0, \tag{10}$$

then Condition (4) fails. Substitutability is a reasonable assumption in a variety of contexts, and could hold for Pixar and Disney.

Pixar and Disney's efforts would be substitutes in the following circumstance. Let a be the film's "quality" and b be marketing activity. Suppose a customer goes to the movies either if a friend recommends it or if he is impressed by the marketing. Let $z(a)$ be the probability that a friend does not recommend it ($z' < 0$) and let $y(b)$ be the probability

17. A secondary reason for an option would arise if bargaining were costly: The parties gain by avoiding bargaining over the price in equilibrium, since the principal will exercise her option on the equilibrium path of our model.

that he is not impressed by the marketing ($y' < 0$). Assuming independence, the probability he goes to the movie is $1 - z(a)y(b)$, which has a negative cross partial derivative, implying that efforts a and b are substitutes.

On the other hand, a large motivation for trade between principal and agent could be the complementary talents they bring to production. For a substantial class of agency problems, then, we should expect Condition (4) to fail, so that we cannot achieve the first best using simple option contracts.

Observe that we can interpret trading situations in which the asset is valueless to the agent, as in Che and Chung (1996) and Che and Hausch (1999), to be ones in which investments are "maximally" complementary —action by the principal (including, possibly, just taking possession) is necessary in these situations for there to be any positive return to the agent's investment. Hence it is not surprising that we—like Che and Hausch—find achieving the first best to be difficult in these situations (at least when there can be renegotiation). In particular, option contracts will *fail* to achieve the first best.

If the agent is risk averse, then this complements-substitutes dichotomy can be complicated by how the agent's wealth affects his attitudes toward risk and how his actions affect the gamble he faces if he keeps the asset. The dichotomy is maintained in its purest form, however, if there are no wealth effects and the riskiness of the return, r, is independent of a. For instance, if $u(w) = 1 - e^{-w}$ and r is distributed normally with mean $\mathrm{R}(a, b)$ and variance τ^2, then

$$CE(a, p_1) = R(a, 0) - \tfrac{1}{2}\tau^2.$$

In this case, the risk premium, $\frac{1}{2}\tau^2$, is independent of the agent's action, a. In other settings, it is quite possible that the agent's action does affect the risk premium. If it reduces the risk premium, this will enhance the threat-point effect and thereby the possibility of an efficient outcome. Conversely, if the risk premium rises with a, then this reduces the threat-point effect, making the holdup effect dominate for a larger set of parameter values.

4. General Mechanisms

When the first best is unattainable with an option contract—that is, when Condition (4) fails—the obvious question is whether the first best could be achieved by a more general mechanism. Here we show that the answer is "no" if the agent is risk neutral.

We now assume that the agent is risk neutral. Without loss of generality, assume the agent's utility is $w - a$. Observe that the first-order condition of Equation (2) reduces to $V'(a^*) = 1$ in this case.

Consider a general announcement mechanism in which both agent and principal make announcements, $\hat{a}_A$ and $\hat{a}_P$, respectively, about the

agent's actions. Conditional on these announcements, the agent is paid $p(\hat{a}_A, \hat{a}_P, \chi)$ and ownership of the asset is given to the principal ($\chi = 1$) with probability $x(\hat{a}_A, \hat{a}_P)$ and to the agent ($\chi = 0$) with probability $1 - x(\hat{a}_A, \hat{a}_P)$. We continue to assume that renegotiation is possible after the mechanism is played out. Observe that if the principal receives ownership–the allocation is efficient—then there is no scope for renegotiation at this stage. We could also allow for renegotiation after announcements but *before* the mechanism is executed, but since the agent is risk neutral, there are no gains from renegotiation at this point.

Define:

- $\tilde{v}(a) \equiv \int_r^\infty r f(r \mid a, 0)\, dr$ (agent's expected value of owning the asset at the end);
- $S(a) \equiv V(a) - \tilde{v}(\mathrm{a})$ (surplus from trading asset after the mechanism gives the agent ownership);
- $P(\hat{a}_A, \hat{a}_P, a) \equiv \sigma_A[S(a)] + \tilde{v}(a) + p(\hat{a}_A, \hat{a}_P, 0)$ (total payment to agent if the mechanism gives him initial ownership and the principal must bargain to acquire asset);
- $\tilde{w}(\hat{a}_A, \hat{a}_P, a) \equiv x(\hat{a}_A, \hat{a}_P)p(\hat{a}_A, \hat{a}_P, 1) + [1 - x(\hat{a}_A, \hat{a}_P)]P(\hat{a}_A, \hat{a}_P, a)$ (the agent's expected wage (utility) before playing the mechanism); and
- $w(a) \equiv \tilde{w}(a, a, a)$.

The following lemma establishes a preliminary result that will be repeatedly applied in this section.

Lemma 1. Assume strict monotone sharing in renegotiation. Assume, too, that $V'(\cdot)$, $\tilde{v}'(\cdot)$, and $\sigma_A'[S(\cdot)]$ are continuous in a neighborhood of action $\hat{a} > 0$. Then *no* mechanism implements $\hat{a}$ if

$$\sigma_A'[S(\hat{a})]V'(\hat{a}) + \left(1 - \sigma_A'[S(\hat{a})]\right)\tilde{v}'(\hat{a}) < 1. \tag{11}$$

Intuitively the need to induce truth-telling from the parties effectively eliminates the use of the payments $p(\hat{a}_A, \hat{a}_P, \chi)$ to provide positive incentives for effort: If the payments for announcements $\langle \hat{a}, a \rangle$ are large, then the agent will prefer to shirk, a, and claim he worked hard, $\hat{a}$; or if payments are small, then even if the agent works hard, $\hat{a}$, the principal will claim he shirked, a. Hence the maximum incentives for effort that the agent can be given come from renegotiation. If these maximum incentives are less than the agent's marginal cost of effort at the target level of effort—if Expression (11) holds—then there is no way to induce that target level of effort.

Our first application of Lemma 1 is to show that Condition (4) is necessary for the first best to be achievable with a risk-neutral agent.

Observe that with a risk-neutral agent, Condition (4) failing to hold is equivalent to

$$V'(a^*) > \tilde{v}'(a^*). \tag{12}$$

Proposition 5. Assume strict monotone sharing in renegotiation. Assume, too, that $V'(\cdot)$, $\tilde{v}'(\cdot)$, and $\sigma_A'[S(\cdot)]$ are continuous in a neighborhood of the first-best action, a^*. Then the first best is unattainable if Condition (4) fails.

Proof. Since a^* is the first-best action, $V'(a^*) = 1$. The failure of Condition (4) implies $\tilde{v}'(a^*) < V'(a^*)$. Combining this inequality with the assumption of *strict* monotone sharing, we see that Inequality (11) holds for $\hat{a} = a^*$. The result then follows from Lemma 1. ■

Suppose, instead that Condition (4) is met. Observe that, if the agent is risk neutral,

$$p(a, p_1) = \sigma_A[S(a)] + \tilde{v}(a),$$

where $p(a, p_1)$ is as defined in Section 3. Hence, provided

$$\sigma_A[S(a)] + \tilde{v}(a) - a \tag{13}$$

is ideally quasi-concave, then the first best is attainable by Proposition 4. This observation and Proposition 5 yield:

Proposition 6. Suppose (i) a risk-neutral agent; (ii) strictly monotone sharing in renegotiation; (iii) Expression (13) is ideally quasi-concave in a; and (iv) $V'(\cdot)$, $\tilde{v}'(\cdot)$, and $\sigma_A'[S(\cdot)]$ are continuous in a neighborhood of the first-best action, a^*. Then the following are all equivalent:

- The first best is attainable if and only if Condition (4) holds;[18]
- The first best is attainable if and only if it can be obtained by an option contract; and
- The first best is attainable if and only if the principal's and agent's actions are substitutes on the relevant margin (i.e., in the sense of Expression (9)).

When the first best is unattainable, what is the optimal contract? We explore this question for the case in which Expression (13) and $V(a) - a$ are ideally quasi-concave; the latter quantity equaling social surplus as a

18. The results of Segal and Whinston (1997), independently established, can be applied in our framework to show that any message game can be replaced with a (possibly randomized) uncontingent contract that implements the same investments. By studying uncontingent contracts, one could then obtain our result that the first best is attainable with a risk-neutral agent if and only if Condition (4) holds.

function of the agent's effort given a risk-neutral agent. The optimal (second-best) contract maximizes this quantity subject to incentive-compatibility constraints and the requirement that the agent's equilibrium expected utility equal zero.

Proposition 7. Suppose (i) a risk-neutral agent; (ii) strictly monotone sharing in renegotiation; (iii) Expression (13) and $V(a) - a$ are ideally quasi-concave in a; and (iv) $V'(\cdot)$, $\tilde{v}'(\cdot)$, and $\sigma_A'[S(\cdot)]$ are continuous. If the first best is unattainable (i.e., if $V'(a^*) > \tilde{v}'(a^*)$),[19] then the second-best outcome is achieved by a *simple purchase* contract: The agent purchases the asset for

$$p^{**} \equiv \sigma_A[S(a^{**})] + \tilde{v}(a^{**}) - a^{**},$$

where

$$a^{**} = \min\{a \in [0, a^*] \mid \sigma_A'[S(a)]V'(a) + (1 - \sigma_A'[S(a)])\tilde{v}(a) \leq 1\};$$

and the principal has no future rights (i.e., she can reacquire the asset through renegotiation only).

Remark 3. Observe that a simple purchase contract can be replicated by an option contract with a high-enough strike price (i.e., $p_2 > \sigma_A[S(a^{**})] + \tilde{v}(a^{**})$). In this sense, we can conclude that the optimal contract is always an option contract.

Recall that the requirement that the agent's equilibrium utility equal zero was a normalization that allowed us to avoid modeling the initial bargaining. We could dispense with it here and reinterpret the problem as one in which both parties have reservation utilities of zero. Then, provided

$$-\sigma_P[S(a^{**})] \leq p^{**} \leq \sigma_A[S(a^{**})] + \tilde{v}(a^{**}) - a^{**},$$

it readily follows that a simple purchase contract will provide appropriate incentives for achieving the second best and will satisfy both parties' participation constraints. A statement analogous to Proposition 7 can be made when the asset initially belongs to the principal and $\tilde{v}'(a^*) < V'(a^*)$: An optimal, second best arrangement would be for the principal to relinquish ownership ex ante and simply bargain for the asset after the agent has supplied effort.

19. If $V'(a^*) = \tilde{v}'(a^*)$, then it's straightforward to see that a simple purchase contract achieves the first best.

Given a risk-neutral agent (e.g., a firm), we can combine Propositions 6 and 7 to see how we can make inferences about the underlying technology from the parties' choice of contracts: If the parties sign an ex ante agreement that gives the principal repurchase rights, then investments must be general on the margin (i.e., substitutes); if, instead, the parties sign an ex ante agreement without repurchase rights or no ex ante agreement at all (as would be the case if the agent initially owned the asset), then investments must be specific on the margin (i.e., complements).

Figure 2 illustrates the intuition behind the results of this section. The graphed curve is

$$\sigma_A[S(a)] + \tilde{v}(a) + p_1 - a,$$

the agent's utility if the principal's option (if any) is not exercised and the downward-sloping line is $p_1 + p_2 - a$, his utility if the principal exercises her option. Given rational play by the principal, the agent's

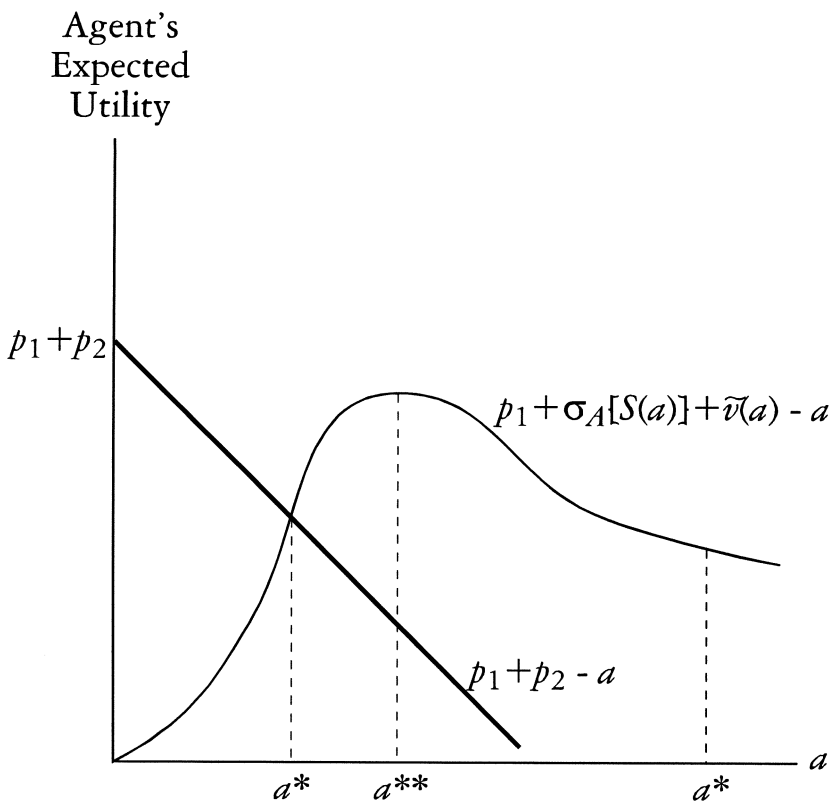

Figure 2. Optimality of option contracts versus "no contract."

utility as a function of a is the lower envelope of these two functions. Two candidate values for the first-best effort, a^*, are shown. If a^* is the candidate on the left, then the agent would overexert himself absent an option contract—he would choose a^{**} instead of a^*. As noted above, an option serves to prevent overexertion and causes the agent to choose the first-best action, a^*. If, however, a^* is the candidate on the right, then the agent under exerts himself given a simple purchase contract. As the figure illustrates, switching to an option contract cannot improve matters; the only possible effect of an option contract in this case is to undermine incentives further. Since, as Proposition 1 essentially establishes, the agent can't be given more powerful incentives than when his reward function is $\sigma_A[S(\cdot)] + \tilde{v}(\cdot)$, it follows that in this case the best possible outcome is that achieved under a simple purchase contract.

These results can be related to those of Che and Hausch (1999). Like us, they show that it can be optimal for risk-neutral parties not to contract over future exchanges when investments are complementary. Unlike here, however, the first best cannot be attained in Che and Hausch. The reason for this is that they, unlike us, assume the asset has value only if traded. Hence in their model, there are two sources of investment incentives for the agent: the degree to which his investment reduces his cost of production *should trade occur* and the degree to which his investment enhances the principal's value for the good. Under an option contract with a low p_2, trade is almost certain to occur without renegotiation. In this case, only the cost-reduction incentive operates. In contrast, if p_2 is set high, then trade will occur only following renegotiation. Depending on his bargaining power, the agent will capture some of the surplus from trade—the difference between the principal's value and his production cost—so incentives stem from a combination of the two sources scaled by his share of the surplus.[20] If his share is small, then his incentives are greater if p_2 is set low; if his share is large, then his incentives can be greater if p_2 is set high. This is why, in Che and Hausch, the optimal contract depends on the production process *and* the renegotiation sharing rule. This is also why in their model the first best is generally not attainable: There is not reason to expect reducing his private production costs to provide the agent with the appropriate social incentives (the low-p_2 case) and, as we've seen, the holdup effect prevents the first best in the other (high-p_2) case. Put somewhat differently, the "threat-point effect" goes the "wrong way" in Che and Hausch: By investing more, the agent increases his utility from trade (lessens his cost), which undercuts his ability to extract surplus in renegotiation. It is thus not surprising that Che and Hausch find themselves focusing on *second*-best outcomes.

20. In Che and Hausch (1999), $\sigma_A(\cdot) \equiv \bar{\sigma} \in (0, 1)$.

In some sense, our model would be closer to Che and Hausch (1999) if we allowed a to have a negative marginal contribution for the agent; that is, if

$$\tilde{v}'(a^*) < 0 < V'(a^*).$$

This condition would hold, for instance, if the customization of an object (e.g., a car) for the principal *reduced* its value to the general public. Fortunately Propositions 3, 6, and 7 still apply equally well if the agent's effort reduces his private value. In this case, the first best can't be achieved because the threat-point effect actually intensifies the holdup effect—investment lowers the value of the project to the agent on the margin.[21]

We have only considered general mechanisms for the risk-neutral case. It is conceivable that when the agent is risk averse, a general contract might perform better than an option contract. Elsewhere we have derived conditions for efficiency when Condition (4) fails (see Edlin and Hermalin, 1997). These conditions, however, seem extremely limited (and complex) and might even be impossible to satisfy.

5. Is Renegotiation a Relevant Threat?

The view of Bernheim and Whinston (1998) and Nöldeke and Schmidt (1998) is that renegotiation is, essentially, irrelevant: that is, a Demski–Sappington contract is renegotiation proof and the possibility of renegotiation does *not* prevent the parties from achieving the first best. Our article is motivated by the belief that renegotiation is a relevant threat in many contractual settings, in large part because the parties have limited abilities to structure contractually how bargaining will be done in future renegotiation. This is why we've looked beyond take-it-or-leave-it bargaining and considered situations in which surplus sharing is unavoidable. It's also why our game is not over—that is, free from renegotiation—until the physical allocation is efficient. Because our view of the renegotiation threat differs markedly from that in some of the related literature, it seems worth contrasting our views with those of others.

21. We could also consider the possibility that $V'(a^*) < 0$. However, in an agency model—that is, a model in which trade is always efficient—this case is not interesting: The principal's marginal value for the asset can be nonpositive at the *efficient* level of investment, a^*, only if $a^* = 0$—but the least-cost action (i.e., 0) can always be implemented at first-best cost. On the other hand, in a trade model—that is, a model in which trade may or may not be efficient—this case could be of interest if cost-saving investments by the agent reduce costs more on the margin than they reduce the principal's value for the good. See Edlin et al. (1998) for more on the relationship between agency and trade models.

To begin, consider our requirement that the parties cannot commit to an inefficient allocation (here, one in which the agent owns the asset at the end of the day). This distinguishes our work, for example, from Bernheim and Whinston's. In their work, if the principal does not exercise her option to buy, then they assume the game is over; even though the allocation at that point is inefficient. In terms of our model, this would be equivalent to assuming that the parties could restrict renegotiation to before the exercise date of the option. Such a restriction would render incredible the principal's threat to refuse to exercise her option, thus eliminating the holdup effect. It follows *if* the parties could impose such a restriction, then they would want to, since the holdup effect is what prevented the Proposition 1 (Demski–Sappington-like) contract from being efficient. Committing to foregoing renegotiation of inefficient outcomes strikes us as a difficult commitment to make, so in many circumstances we expect renegotiation to be a relevant threat until the party who values the asset more (here, the principal) owns the asset. Without the "game over" restriction, the principal has the incentive with a Bernheim–Whinston option to let it expire and, subsequently, bargain, as we have shown.

Nöldeke and Schmidt have a different idea for ensuring that the principal repurchases the asset at the high break-even price. Their idea is to set the option exercise date (together with any renegotiation) after the principal invests. After the principal invests, they assume that the agent and principal attach equal values to the asset. This equal-values assumption precludes any gainful renegotiation of ownership at this stage. Moreover, the principal will now exercise his option because once he has sunk positive expenditures, the exercise price (once break-even) looks attractive. Offers by the principal to purchase at a lower price before his investment date will be rejected, because the threat to forgo investment and exercise is incredible.

Two things can go wrong with this argument. First, the equal-values assumption, which precludes renegotiation at this stage, need not hold. It would fail to hold, for example, if the agent is risk averse or if the principal otherwise has an idiosycratically higher value for the asset.[22]

A second problem with the Nöldeke–Schmidt solution is that their solution denies the basic insight of the "outside-option" principle [see, e.g., Sutton (1986:714) or Osborne and Rubinstein (1990:54–63)]. In our setting, the principal has the option to invest and repurchase the asset. The outside-option principle (motivated by explicit extensive-form renegotiation games) says that to solve such a bargaining game, one should first find the payoffs under the Rubinstein bargaining solution, ignoring the option, and then compare the principal's Rubinstein bargaining payoff with her payoff from exercising her option. The principal should get the maximum of these two quantities. In the Nöldeke–Schmidt case,

22. The principal's greater value could create the motive for trade in the first place.

because the option of investing and then purchasing has 0 value by construction, the outside-option principal suggests that the Rubinstein solution, ignoring the option, is the relevant payoff.

To be more concrete, the difficulty with the Nöldeke–Schmidt solution (even in the risk-neutral case) is that it may prove impossible to prevent renegotiation until after the principal invests. In particular, the principal has the incentive to delay investing until she has purchased the asset at a satisfactorily low price.

A threat to delay investing seems entirely credible in many circumstances. Suppose, hypothetically, that Pixar finished making *Toy Story* in April 1995 and Disney was to make marketing expenditures in May, and exercise its option in June, with the movie receipts coming in July. Throughout April, Disney proposes to buy the film at a price below the break-even option price. Pixar steadfastly refuses these offers, thinking that Disney's threats to neither invest nor purchase are not credible. On May 1, Disney can sink marketing expenditures as planned, but if it does so, then its threat not to exercise indeed becomes incredible and Disney will wind up paying the full option price. Disney's alternative is to delay marketing expenditures. If Pixar continues to fantasize about getting the full option price, Disney may choose to delay until July, when the option has expired and postpone the release of the movie by two months. Once the option expires, it is hard to see how it could affect bargaining and constrain Disney's ability to buy at a low price. In the final analysis, it seems unlikely that Disney will invest in marketing or distribution before it owns the movie.

Nöldeke and Schmidt (1998) have responded to this criticism of ours by suggesting that the parties could give the principal a nonexpiring option that could be exercised at any time. This, however, doesn't really solve the problem of the principal delaying her investment. On the one hand, if delay reduces the value of her investment, then even a moment's delay means that the principal *loses* by exercising her option. Therefore, after a delay, the option would become irrelevant by anyone's estimation and the principal could presumably negotiate for a share of the surplus (assuming the delay doesn't eliminate all value). Suppose, on the other hand, that delay is possible but doesn't affect returns apart from time discounting (i.e., conditional on delay having occurred, the return from the principal's investment is the same). Now, investing and exercising the option yield the principal zero return. In this case, bargaining could be modeled as a standard alternating-offer game, as in Sutton (1986:714), with the principal holding an "outside option." But, as above, this means the option is effectively irrelevant.[23]

23. From our earlier discussion of Demski and Sappington (1991), we know the principal's option can't have positive value if the agent has made his equilibrium investment; while the equal-valuation assumption tells us that *after* she invests it can't have negative value (she's no worse with the option than without). The option is thus valueless.

To be sure, there will certainly be some situations in which (i) the technology fixes a date when the principal must invest or forever forgo investing (i.e., delay is impossible) and (ii) the parties value the asset equally conditional on the principal having invested. In these cases, the Nöldeke and Schmidt (1998) solution will work just fine even when investments are complementary on the margin.

To summarize, renegotiation might be irrelevant, but the assumptions that make it irrelevant are often overly strong and, if taken seriously, could render the contracting problem vacuous. Although *technological* reasons may sometimes prevent delay, we've argued that the parties typically cannot *contractually* block delay: Contractually blocking delay means, implicitly, giving the bargaining power to the agent. But, again taking that assumption seriously means there's no holdup problem in the first place. If there is a real threat of holdup, then there ought to be a real threat of delay, which means that even if the contract suggests a different timing, our timing may emerge as the relevant and actual timing of the game.

6. Conclusion

Demski and Sappington (1991) established that observable but unverifiable information about the agent's action can be profitably exploited in an agency problem. In particular, they established conditions in which the first best is achievable despite an inability to verify the agent's action. Their analysis can, however, be faulted for ignoring renegotiation. In this article we've allowed for renegotiation at a general level. Although it is problematic to provide an agent with efficient incentives if (1) contracts will be renegotiated when they prescribe inefficient outcomes and (2) the parties *share* the gains from such renegotiation, we've nevertheless shown that some of Demski and Sappington's (1991) conclusions about efficiency continue to hold, at least under certain conditions.

When renegotiation is a relevant threat—as we've argued it is likely to be—achieving the first best depends on whether the threat-point effect dominates the holdup effect. In turn, as we showed, this largely depends on whether the agent and principal's actions are productive substitutes or complements *on the margin*. That is, on whether investments are general or specific, respectively, on the margin. Indeed, if the agent is risk neutral—or in the CARA case we considered—complements imply the holdup effect dominates and the first best is unattainable; while substitutes imply the threat-point effect dominates and the first best is achievable with a simple option contract. It is worth noting that investments can be specific on average but general at the margin, and the margin is what matters.

This dichotomy between complementary and substitutable actions could offer insights into what activities take place within a firm and which are done through the market: If, as is often assumed, control is

greater within the firm than outside, then it might be efficient for a firm to encompass complementary activities because they are difficult to procure contractually.[24] For example, it may have made sense for General Motors to buy Fisher Body, because General Motors' efforts at designing and marketing automobiles were complementary to Fisher Body's efforts to make auto bodies.[25] That is, our analysis sheds light on the relationship between the underlying technology and the "make-or-buy" decision.

In addition, the substitutes-complements dichotomy offers insights into the type of contracting we can expect to see absent integration. If investments are substitutes, then we can expect to see option contracts used. In contrast, if investments are complements, then we may expect to see a simple purchase contract. In this latter case, we might also expect the parties to find verifiable signals that are correlated with the agent's action and that can thus be used to structure agency contracts like those considered in Hermalin and Katz (1991) or Edlin and Hermalin (1998).

Work remains to be done in this area. For instance, one could reexamine how the agent's risk aversion could be better exploited in a general mechanism. Alternatively, one could recognize that our efficiency results with risk aversion could be undone by introducing noise: Following Hermalin and Katz (1991), imagine that there is "leakage." If information about the return, r, leaks prior to renegotiation, then the agent's compensation could be stochastic even with renegotiation: Suppose, for instance, that an unverifiable signal, ρ, about the distribution of r is observed prior to renegotiation. Then the agent's compensation under an option contract will be $CE(a, p_1, \rho) + \sigma_A[S(a, p_1, \rho)]$, which is stochastic if ρ is stochastic given a. Consequently, with a risk-averse agent, the first best will generally be unattainable.

In summary, this article has shown that the parties ability to achieve the first-best outcome in an agency problem can depend on a number of factors. Two factors in particular—the underlying production technology and whether the bargaining game in renegotiation results in sharing the surplus—are critical. Contrary to what other works may seem to suggest, options are no panacea. In particular, they don't cure the holdup problem (unless one wishes to impart to them unreasonable commitment value). To the extent they are useful, it is to prevent overexertion by the agent.

24. Although coming from a rather different model, Grossman and Hart (1986) reached a similar conclusion. It is worth noting, however, that, more recently, Chiu (1998), working in a similar vein to Grossman and Hart, has challenged their conclusion as being overly sensitive to the assumed bargaining games between the parties.

25. General Motors' efforts expanded the market for their cars which made any efforts by Fisher more valuable.

A. Appendix

Proof of Proposition 3. Suppose not. The agent's utility is

$$u\big(\min\{p(a, p_1), p_2\} + p_1\big) - a,$$

since the principal exercises her option if and only if $p_2 \leq p(a, p_1)$. Since $p(\cdot, p_1)$ is continuous, the agent will never choose a such that $p(a, p_1) > p_2$ (unless $a = 0$)—he could increase his utility by reducing a. Since, by assumption, $a^* > 0$, it follows that

$$u'\big(p(a^*, p_1) + p_1\big)\frac{\partial p(a^*, p_1)}{\partial a} \geq 1 \tag{14}$$

(where equality holds if $p(a^*, p_1) < p_2$). Since we've supposed that the first best is achieved,

$$p(a^*, p_1) + p_1 = u^{-1}(a^*)$$

[i.e., the constraint in Expression (1) is satisfied]. Using Equation (2), the first-order condition, Expression (14), can be rewritten as

$$\frac{\partial p(a^*, p_1)}{\partial a} \geq V'(a^*),$$

which contradicts Expression (8). ■

Proof of Proposition 4. Set $p_2^* = p(a^*, p_1^*)$. Then the agent chooses a to maximize

$$u\big(\min\{p(a, p_1^*), p_2^*\} + p_1^*\big) - a.$$

Since $p_2^* = p(a^*, p_1^*)$ and $p(\cdot, p_1^*)$ is increasing, it is never optimal for the agent to choose an $a > a^*$. Hence the agent's problem is

$$\max_{a \leq a^*} u\big(p(a, p_1^*) + p_1^*\big) - a. \tag{15}$$

Since $u(p(a, p_1^*) + p_1^*) - a$ is ideally quasi-concave in a, a^* solves Program (15) if

$$u'\big(p(a^*, p_1^*) + p_1^*\big)\frac{\partial p(a^*, p_1^*)}{\partial a} - 1 \geq 0. \tag{16}$$

Using the definitions of p_1^*, p_2^*, and Equation (2), we can rewrite Expression (16) as

$$\frac{\partial p(a^*, p_1^*)}{\partial a} \geq V'(a^*).$$

This inequality holds if $\sigma_A'[S(a^*, p_1^*)] = 1$ or if sharing is monotonic and Condition (4) holds. ■

Proof of Lemma 1. We restrict attention to incentive compatible direct revelation mechanisms (without loss of generality according to the revelation principle), and we will show that no such mechanism can induce $\hat{a}$. Incentive compatibility requires that

$$\tilde{w}(a, a, a) \geq \tilde{w}(\hat{a}, a, a) \quad \text{and}$$
$$\tilde{w}(\hat{a}, \hat{a}, \hat{a}) \leq \tilde{w}(\hat{a}, a, \hat{a}).$$

When $a < \hat{a}$, these can be interpreted, respectively, as saying that the agent can't improve his payoff by claiming to have worked hard when he shirked and that the principal can't lower the wage by claiming the agent shirked when he didn't. Combining these inequalities yields

$$\begin{aligned} w(\hat{a}) - w(a) &\leq \tilde{w}(\hat{a}, a, \hat{a}) - \tilde{w}(\hat{a}, a, a) \\ &= (1 - x(\hat{a}, a))\big[P(\hat{a}, a, \hat{a}) - P(\hat{a}, a, a)\big] \\ &= (1 - x(\hat{a}, a))\big(\big[\sigma_A[S(\hat{a})] + \tilde{v}(\hat{a})\big] \\ &\qquad - \big[\sigma_A[S(a)] + \tilde{v}(a)\big]\big). \end{aligned}$$

Using the fact that $x(\hat{a}, a) \geq 0$, together with the mean value theorem yields

$$w(\hat{a}) - w(a) \leq \big(\sigma_A'[S(\tilde{a})]V'(\tilde{a}) + (1 - \sigma_A'[S(\tilde{a})])\tilde{v}'(\tilde{a})\big)(\hat{a} - a) \tag{17}$$

for some $\tilde{a} \in (a, \hat{a})$. Observe also that Expression (11) and the (local) continuity of $V'(\cdot)$, $\tilde{v}'(\cdot)$, and $\sigma_A'[S(\cdot)]$ imply that there exists an $a' < \hat{a}$ such that

$$\sigma_A'[S(\tilde{a})]V'(\tilde{a}) + (1 - \sigma_A'[S(\tilde{a})])\tilde{v}'(\tilde{a}) < 1$$

for all $\tilde{a} \in [a', \hat{a}]$. Letting $a = a'$, it then follows from Expression (17) that

$$w(\hat{a}) - w(a') < \hat{a} - a';$$

or, rewriting, that

$$w(\hat{a}) - \hat{a} < w(a') - a'.$$

But this inequality means that the agent prefers action a' to action $\hat{a}$; hence $\hat{a}$ is *not* implementable by any mechanism. ■

Proof of Proposition 7. Since $1 = V'(a^*) > \tilde{v}'(a^*)$ and renegotiation is strictly monotone,

$$\sigma_A'[S(a^*)]V'(a^*) + (1 - \sigma_A'[S(a^*)])\tilde{v}(a^*) \leq 1.$$

Since Expression (13) is ideally quasi-concave, Expression (11) holds for all $\hat{a} > a^{**}$. From Lemma 1, no $\hat{a} > a^{**}$ is implementable. Since $a^{**} < a^*$ and a^* maximizes $V(a) - a$, which is ideally quasi-concave in a, the best we can hope to do is find a mechanism that implements a^{**}. The agent chooses his action to maximize

$$\sigma_A[S(a)] + \tilde{v}(a) - a - p^{**}.$$

If $a^{**} = 0$, then the agent will clearly choose a^{**}. Suppose therefore that $a^{**} > 0$. By construction, the first-order condition is satisfied at $a = a^{**}$:

$$\sigma_A'[S(a^{**})]V'(a^{**}) + (1 - \sigma_A'[S(a^{**})])\tilde{v}'(a^{**}) - 1 = 0.$$

Since this function is ideally quasi-concave, the first-order condition is sufficient; that is, a simple purchase contract implements a^{**}. By construction, p^{**} is such that the agent's equilibrium utility is zero. ■

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