13 Option contracts and the holdup problem*

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1. Introduction
Any contract that is enforced through money damages, as opposed to specific performance, is, in some sense, an option contract. The performing party has the option to perform or pay damages. That said, contracts are normally only referred to as option contracts if it ‘is a promise which meets the requirements for the formation of a contract and limits the promisor’s power to revoke an offer’ (Restatement (Second) of Contracts Section 25). Economic analysis of option contracts has been recent, and it has almost exclusively focused on the efficacy of option contracts as a solution to the holdup problem. While, as Katz (2004) has noted, both the optimal design of option contracts and the special doctrinal treatment of option contracts are worthy of detailed analysis, this chapter will follow the existing literature and focus on the conditions under which option contracts provide a robust solution to the holdup problem. In reviewing this literature, the chapter will find that the details of the model, and in particular, the bargaining process, are critical in determining whether or not the holdup problem is a significant and inevitable feature in a non-trivial number of contractual situations.

The next section of this chapter describes the holdup problem in detail and discusses its importance to creating a coherent theory of firm boundaries. It also introduces the mechanism by which option contracts might provide a contractual solution to the holdup problem. Section 3 discusses the extent to which option contracts can provide a robust solution to the holdup problem in situations where parties must invest in the relationship simultaneously. Section 4 discusses the efficacy of option contracts in sequential investment settings. Section 5 concludes.

* I thank Ronen Avraham for helpful comments.
1 Katz (2004) is an important exception. Scott and Triantis (2004) and Avraham and Liu (2006), among others, also discuss options embedded in contracts, though they do not focus specifically on explicit option contracts.
2. The Holdup Problem

The holdup problem occurs when parties to a relationship have an incentive to under-invest in their relationship (relative to the amount that would maximize the expected surplus from their relationship) because, while each party bears all the cost of its investment, the benefits of the investment are shared between the two parties. This can happen if the profitability of the relationship between two parties depends on the magnitude of the relationship-specific investments. An investment is relationship-specific if it creates substantially more value if the two parties deal with each other than if they do not. Of course, there will be no holdup problem if the investments can be precisely specified in advance and easily verifiable by a court ex post.2

If one or both of these conditions are not satisfied, then the relationship-specific investments are non-contractible in the sense that it is not possible to write a contract requiring a specific investment level that can be enforced in court. In this case, a holdup problem can emerge because the contract between the two parties may need to be renegotiated after the investment cost is sunk. Typically, holdup models assume that there is too much uncertainty ex ante (before the investments are made) to write a contract that will specify an efficient trade in every possible contingency. In these models, because at least some features of the efficient trade must be negotiated after the parties have invested, there is the potential for holdup. This problem was first identified and discussed in Williamson (1975, 1985), Klein et al. (1978), Grout (1984), and Hart and Moore (1988). Holdup has played an important role in the recent literature about determining the optimal boundaries of the firm as a way to mitigate holdup problems (Grossman and Hart 1986; Hart and Moore 1990).

This literature on the importance of holdup in the theory of the firm has spawned a large number of articles suggesting that holdup is not as serious a problem as many have suggested. These articles argue that there are contractual solutions that can solve the under-investment problem that holdup creates. If this is the case, then the theories of the firm that rely on the choice of firm boundaries to mitigate holdup problems are built on an improper foundation. The main proposed contractual solution to the holdup problem involves the use of option contracts. Determining the ability of option contracts to solve the holdup problem is critical to assessing the large literature on the theory of the firm that is based on the existence of a holdup problem.

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2 In fact, even if investments cannot be specified in advance but the court can verify not only the investments but whether or not they are efficient ex post, then there should also be no holdup problem.
As Rogerson (1992) has shown, if initial contracts can preclude renegotiation, the contracts can solve the holdup problem quite generally. As a legal matter, however, prohibiting parties from renegotiating a contract is difficult, if not impossible. Thus, defenders of the incomplete contracts theory argued that once it is recognized that contracts must be renegotiation-proof, the holdup problem re-emerges. In the early 1990s, most papers examining renegotiation-proof contractual solutions to the holdup problem focused on contracts that specified the renegotiation protocol (Chung 1991; Aghion et al. 1994). Because there was some criticism of the realism of specifying a renegotiation protocol in advance, much of the subsequent literature on solutions to the holdup problem focused on option contracts.

3. Option Contracts in Simultaneous Investment Settings

3.1. Option Contracts and the Basic Holdup Problem
Nöldeke and Schmidt (1995) is one of the first papers to suggest that option contracts could achieve first-best investment levels in standard holdup models even without being able to contractually specify the renegotiation process in advance. Their paper re-considers the Hart and Moore (1988) model of the holdup problem. In this model, at date zero, a buyer and a seller contract over the terms of trade for one unit of an indivisible good. At this time, they specify two prices. The buyer pays the seller $p_1(p_0)$ if the good is (is not) traded at date 2 (the court can only verify whether trade occurred or not). Between date 0 and date 1, the parties make relationship-specific investments. These investments are selfish in that the seller’s investment affects only her cost of production, $c$, and the buyer’s investment affects only his valuation, $v$, of the good to be traded. These investments are observable to the parties, but they are non-verifiable, so they cannot be contracted upon. At date 1, both parties observe both the level of the investments and the state of the world (the seller’s cost and the buyer’s valuation). Also at date 1, the parties have the opportunity to renegotiate the contract.

At date 2, the seller decides whether or not to exercise her option to

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3 MacLeod and Malcomson (1993) showed that if there was some contractible variable correlated with investment levels, then the first best can generally be achieved.

4 Hermalin and Katz (1993) proposed a fill-in-the-price contract that effectively served as an option contract and showed how, under certain assumptions, this could generate first-best investment levels even with renegotiation.

5 Contract theorists use the term selfish without any pejorative connotation.
deliver the good (the effective strike price of this put option is $p_1 - p_0$) and the buyer decides whether to accept delivery. In Hart and Moore, trade is effectively a mutual option. Since they assume the court can only verify if trade occurred, no trade occurs (resulting in a payment of $p_0$) if either the seller does not deliver or the buyer refuses delivery. If there is no trade at date 2, then the good loses all value to the buyer.

Holdup can occur only because there is uncertainty about whether or not trade is efficient. If trade were always efficient, then a simple fixed price contract would induce efficient investment by both parties. The reason is that if trade is efficient, a fixed price contract will never be renegotiated since doing so can never make both parties better off. Thus, the seller will obtain all the gains from her cost reduction and the buyer will obtain all the gains from his investments that increase the value for the good. This gives both parties efficient incentives to invest.

Since trade may not be efficient, however, fixed price contracts sometimes need to be renegotiated. In Hart and Moore’s model of renegotiation, either party may obtain the surplus from renegotiation depending on the resolution of the uncertainty. This means that both parties have too little incentive to invest to increase the surplus from the relationship since with positive probability they will not benefit from this increase in surplus.

Nöldeke and Schmidt (1998) alter the Hart and Moore model by assuming that a court can verify whether the seller delivered the good. Thus, in their model, only the seller has the delivery option (if the seller delivers, the buyer pays $p_1$ regardless of whether or not he accepts delivery). Nöldeke and Schmidt show that, even with uncertainty regarding the efficiency of trade, once a seller-option contract is feasible, this contract can induce first-best investment levels despite renegotiation. The key to their result is that they assume a renegotiation process which effectively gives all the bargaining power to the buyer. As a result, the buyer necessarily has efficient incentives to invest because he receives all the surplus from renegotiation (thus, he does not share any of the increase in surplus he creates via his investment).

The seller’s incentives are efficient by designing the original contract to

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6 Their renegotiation game has each player sending a new contract to the other party. Then the seller has to decide whether to deliver the good before she knows whether the buyer has agreed to her offer. Thus, by sending any new contract offer to the buyer, she only gives the buyer an option to use the new or the old contract. As a result, only the buyer’s renegotiation offer really matters. He makes this offer only if it is necessary to induce the seller to behave efficiently. Moreover, in this case, since the buyer is effectively making a take it or leave it offer, the buyer obtains all the surplus from renegotiation.
balance two offsetting distortions. The seller’s incentive to trade under the original contract is given by \( p_1 - p_0 \). If this is small, then trade will rarely be optimal for the seller under the original contract (only if she gets a very favorable cost shock, so that \( c < p_1 - p_0 \)). Thus, since she will rarely want to trade under the original contract, this contract gives her very little incentive for cost reduction. Of course, the contract will be renegotiated to induce trade if \( v > c > p_1 - p_0 \). Since the buyer receives all the surplus from renegotiation, the seller’s incentives for cost-reducing investment are too small if \( p_1 - p_0 \) is small.

On the other hand, if \( p_1 - p_0 \) is large, then \( p_1 - p_0 > c \) is quite likely, so the original contract provides very strong incentives for the seller to reduce costs (since trade will occur with high probability under this contract). If \( p_1 - p_0 > c > v \), then the contract will be renegotiated to stop the seller from trading. So, in these cases, cost-reducing investment has no social value, but it still has private value to the seller since it raises the amount the buyer must offer the seller not to trade. Thus, if \( p_1 - p_0 \) is large, the seller’s incentives for cost-reducing investment are too large. By choosing \( p_1 - p_0 \) appropriately, these two conflicting effects can be perfectly balanced to induce the seller to invest efficiently. Notice, however, that if the buyer had the option to refuse delivery, as in Hart and Moore (1988), this scheme would not work since the buyer would simply refuse delivery in this case rather than renegotiate the contract.

3.2. Product Complexity, Cooperative Investment and Holdup

After Nöldeke and Schmidt, incomplete contract theorists worked on developing new models in which the holdup problem is more robust. These models can be divided into two types: complexity models and cooperative-investment models. Segal (1999) and Hart and Moore (1999) show that complexity in the environment can prevent option contracts from solving the holdup problem. These models assume that at date 0 there are a large number of potential goods (widgets) that the parties might find it beneficial to trade at date 1. One of these widgets will be the one that maximizes the surplus from trade (the special widget), but at date zero no one knows which widget is the special widget. Thus, the date 0 contract cannot specify the widget to be traded. At date 0.5, the seller can make a cost-reducing investment that induces the buyer to accept this widget.

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7 Edlin and Reichelstein (1996) also show that balancing conflicting incentives for over and under-investing can produce efficient investment incentives. The conditions under which the first best is achievable are somewhat more restrictive, but their bargaining protocol is somewhat more general. In particular, it does not assume that one party effectively has all the bargaining power in the renegotiation game.
investment which only affects the cost of production for the special widget. That is, the greater the investment, the greater the probability that the special widget (whichever one that turns out to be) will cost $c_1$ instead of $c_2$, $c_1 < c_2$. The cost of the other (generic) widgets are evenly spread between $c_1$ and $c_2$. At date 1, the parties can renegotiate their date 0 contract and trade. In this model, trade of the special widget is always efficient.

Holdup emerges unless the seller has all the bargaining power in the renegotiation game (and if the buyer were to make an investment, holdup would occur in this case as well). Renegotiation always guarantees that the special widget will be traded. The gains from renegotiation depend on the surplus from trading the special widget rather than the widget that would be specified absent renegotiation. This surplus depends on the cost of the producing the special widget. As long as the buyer shares some of the surplus from renegotiation, the buyer obtains some of the benefit from the seller’s cost-reducing investment. This gives the seller insufficient incentives to invest in cost reduction.

In the Hart and Moore (1999) and Segal (1999) models, option contracts cannot eliminate this holdup problem because even these contracts are subject to renegotiation. For example, a contract that gives the buyer the option to specify which good to trade at date 1 would induce the buyer to choose the most expensive widget. If this is not the special widget, then this allows the buyer to gain some additional surplus from renegotiating this contract to specify the special widget after he has chosen the most expensive widget. Similarly, giving the seller the option to choose the widget at date 1 would induce her to choose the cheapest widget. Investment raises the probability that the special widget is cheaper than all the generic ones. But, if there are many generic widgets, one will always be very close in cost to the special widget even when the special widget only costs $c_1$. Thus, the seller’s benefit to having the special widget cost $c_1$ instead of $c_2$ is very small if there are generic widgets whose cost is close to $c_1$.

Che and Hausch (1999) developed the cooperative investment model of the holdup problem. In this model, instead of a seller’s investment only affecting her cost of production and a buyer’s investment only affecting his value for the good, the investments have externalities. That is, the seller’s investment increases the buyer’s valuation and the buyer’s investment reduces the seller’s cost. They show that for an arbitrary division of the

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8 Che and Chung (1999) and MacLeod and Malcomson (1993) also have models of cooperative investments.
9 The investment can have selfish effects as well, but for simplicity I’ll focus on the case in which the investment has only cooperative effects.
surplus from renegotiation, if investments are sufficiently cooperative, no ex ante contract can solve the holdup problem. Even more significantly, they show that there is no ex ante contract that can improve investment incentives over not contracting ex ante at all.

In their model, parties contract at date 0. At date 1, each party makes a relationship-specific investment that can affect both parties’ payoff from trade. At date 2, the state of the world is revealed. At date 3, if the initial contract had option components, the party with the options makes its selection. At date 3.5, this contract can be renegotiated. At date 4, the final contract is enforced and players receive their payoffs.

The effect of cooperative investments in this model can be easily illustrated using a limited version of this general model. Suppose only the seller can make an investment, \( e \), that affects only the buyer’s valuation for the good, \( v \). If renegotiation were not possible, a simple buyer-option contract would solve the holdup problem. Let \( e^* \) be the efficient level of investment. If at date 0, the parties wrote a contract that gave the buyer the option to buy the good at a price of \( p = v(e^*) \), then the buyer would only buy the good if the seller invested at least \( e \geq e^* \). The seller would have no reason to invest any more than this amount. Thus, investment would be efficient.

Notice, however, that the buyer receives no gains from trade (ex post). Thus, with renegotiation, the buyer can do better by refusing to exercise his option at date 3. By so doing, now the buyer and the seller renegotiate the contract at date 3.5. For any date 1 investment \( e \), the surplus from renegotiating after the buyer has chosen no trade is \( v(e) - c \). Say the buyer receives a fraction \( \lambda \) of the surplus from this renegotiation. Then the seller’s ex post payoff is \( (1 - \lambda)(v(e) - c) \). Unless \( \lambda = 0 \), the seller will have insufficient incentives to invest since she bears all the cost, but obtains only a fraction \( (1 - \lambda) \) of the benefits. Thus, with renegotiation, option contracts cannot solve the holdup problem if investments are cooperative.

### 3.3. Option Contracts in Product Complexity and Cooperative Investment Models

Lyon and Rasmusen (2004) take issue with both the complexity model of Hart and Moore (1999) and Segal (1999) and the cooperative investment model of Che and Hausch (1999). They argue that in a more realistic bargaining model for the renegotiation game, buyer option contracts can solve the holdup problem in both cases. Their basic argument rests on what they call their Axiom of Unilateral Action. This axiom states that if a player has an option, he can exercise this option at any time up until the last period of the game when trade must occur. If this option yields this player (the buyer in their paper) a non-negative payoff, then the seller can
refuse to renegotiate at any time, knowing that at the last moment when trade must occur, the buyer will exercise his option.

Recall that in the Hart and Moore model, the prospect of renegotiation would induce a buyer with an option contract to choose the most expensive widget even if this was not the special widget that maximized his payoff. He would do so because this would force the seller to pay him more to agree to substitute the lower cost special widget. Lyon and Rasmusen argue that this conflicts with their Axiom of Unilateral Action. That is, they argue that the seller should be able to refuse the buyer’s attempt at renegotiation because she knows that at the moment it becomes time for the buyer to order the widget, he will switch to choosing the special widget (regardless of what he claimed before) because that maximizes his payoff and he has the power to do so unilaterally. As long as the original contract gives the buyer this continuing option, the prospect of renegotiation will not create holdup because the threat to choose the wrong widget is not credible (so there will be no renegotiation).

Similarly, in the Che and Hausch model, Lyon and Rasmusen argue that the buyer’s attempt to refuse delivery (decline to exercise his option) will not be credible, hence will not induce the seller to renegotiate the contract. The seller can ignore the buyer’s attempt to renegotiate the purchase price after declining the option knowing that the buyer will always decide to exercise this option in the last period. As long as the original contract keeps the option open, which it is in the parties’ joint interest to do because holdup reduces the total surplus to be shared, the buyer-option contract will not be renegotiated. Hence, it will solve the holdup problem.

Wickelgren (2007) argues that the Lyon and Rasmusen critique is not always robust if the trading opportunity is durable (that is, if the trade remains efficient for a long time). Notice that both the product complexity models and the cooperative investment models assume that trade must occur on a fixed date. That is, there is only one opportunity to trade; if the trade date passes, all gains from trade evaporate. If the trading opportunity is durable, then there will be many (perhaps an infinite number) of dates in which there are gains from trade, though these gains will be discounted the later the trade occurs. With a durable trading opportunity, Wickelgren argues that holdup is a robust feature of the cooperative investment model.

The reason relates to the outside option principle of Shaked and Sutton (1984): in an infinite-horizon bargaining game, a player’s unilateral option that eliminates any need for continued bargaining will only affect the outcome of the bargaining game if it gives that player a greater payoff than he would have in the bargaining game without this option. In this case, the outside option is ‘binding’. If an outside option is not binding, then this
player has no incentive to exercise the option since she is better off using the threat of delay to obtain a share of the surplus from the bargain (it is this threat that drives the surplus sharing in standard bargaining models without outside options).

In the cooperative investment model, the buyer’s option is not a binding outside option. The reason is that to induce the seller to invest efficiently, the buyer option contract must allocate all the surplus to the seller. Thus, if there is a durable trading opportunity, after investments are sunk, we have a bargaining game in which the buyer and seller bargain over the trade price and the buyer has a unilateral option to purchase at a fixed price. Because this fixed price gives the buyer no surplus, it represents a non-binding outside option. Thus, according to the outside option principle, it does not affect the bargaining outcome. Wickelgren shows this occurs so long as the opportunity is durable enough (the bargaining game is long enough). It is not necessary for the bargaining game to be infinite-horizon.

In the product complexity model, by contrast, simply making the trading opportunity durable does not undermine the effectiveness of buyer option contracts. Unlike the cooperative investment model, the option contract in the product complexity model can allocate significant surplus to the buyer. By so doing, it can make the option contract a binding outside option. As Shaked and Sutton have shown, if the outside option is binding in a bargaining game with discounting, then trade occurs at the option price. Thus, Lyon and Rasmusen’s Axiom of Unilateral Action applies and the buyer option contract is not renegotiated. That said, Wickelgren shows that the holdup problem can re-emerge (at least under certain parameter values) with a slightly modified version of the Hart and Moore/Segal model. Imagine that instead of the trade just being a one-time decision, the seller must deliver a widget (of the type specified by the buyer) every period. The buyer can, however, in any period change the type of widget he orders. In this variation of the model, the buyer’s choice of widget type is no longer an outside option. Instead, it is a disagreement point. That is, it determines the payoffs of the parties while bargaining, but does not eliminate the gains from renegotiating this choice in the future. This changes the bargaining game in a way that makes the buyer’s threat to choose the most expensive widget credible in some circumstances.\(^\text{10}\) As a result, the

\(^{10}\) Holdup re-emerges either if the buyer has all the bargaining power (makes all the offers) or in an alternating offer game in which there is one widget which increases the seller’s costs (over the special widget) by more than it decreases the buyer’s value.
buyer option contract would be subject to renegotiation, undermining the seller’s incentive to invest.

3.4. The Importance of Timing

Evans (2008) has a very general model of the holdup problem that encompasses both the product complexity models of Hart and Moore (1999)/Segal (1999) and the cooperative investment model of Che and Hausch (1999). It also allows the trading opportunity to be durable. He then considers a simple option contract of the following form as a way of solving holdup problems. The initial contract gives the seller an indefinite option to supply a good. The description of the good and the price in the option, however, are left to be specified by the buyer after both parties have invested and observed the state of nature. Despite the fact that a court cannot observe either the state of nature or the amount each party invests, he shows that the fact that this option can be exercised at any time can create an equilibrium in which both parties invest at the first-best level even when this contract can be renegotiated.

This result is driven by the assumption that the seller can exercise this option immediately after rejecting an offer from the buyer as well as after the buyer has rejected an offer from her. The reason this is critical is that it creates multiple equilibria in the renegotiation game. There is an equilibrium like one in the Rubinstein (1982) game in which the surplus is shared among the players. But, there is also an equilibrium in which the buyer believes the seller will always exercise this option if no other contract is agreed to (an equilibrium that echoes Lyon and Rasmusen’s (2004) Axiom of Unilateral Action). The reason this equilibrium exists even with a durable trading opportunity, whereas it does not in Wickelgren’s (2007) model, is precisely because Evans allows the seller to exercise his option after the buyer has rejected her offer, but before the buyer has an opportunity to counter-offer. As Shaked (1994) has shown, Shaked and Sutton’s (1984) outside option principle does not hold under this alternative assumption.

This second equilibrium allows the buyer to potentially punish the seller for not investing at the first-best level. This occurs because this second

11 Shaked (1994) first showed that there can be multiple equilibria in a bargaining game with outside options if the outside option can be exercised either after rejecting an offer or having an offer rejected. In a different context, Schwartz and Wickelgren (2009) suggest that one party exercising an inefficient outside option after her offer is rejected is unrealistic. Their objection, however, does not apply to the equilibrium in Evans (2008), because in this model exercising the outside option is efficient.
equilibrium is selected when the seller does not invest efficiently, while the Rubinstein equilibrium is selected if she does. Similarly, if the buyer deviates from efficient behavior, a change in the equilibrium selected in the renegotiation game can allow the seller to punish the buyer for these deviations. It is important to note, however, that since Evans’s result relies on multiple equilibria, he does not show that option contracts generate a unique equilibrium that solves the holdup problem.

This result is, however, somewhat restrictive in another way. It relies on there being a sufficiently large surplus from acting efficiently that changing how that surplus is divided based on the investments of the players provides a sufficiently large punishment to deter opportunistic behavior. That is, the holdup problem arises in regular contracting situations because the share of the surplus to be divided is fixed (due to the assumption of a unique equilibrium in the renegotiation game). Privately optimal investment with a fixed share of the surplus (less than one) is typically less than the socially optimal level of investment. But, if there is a discontinuous jump in one’s share of the surplus if one invests efficiently, then, provided this jump is large enough, one can generate efficient incentives to invest even if the actual share one receives is less than one. Of course, the larger is the total surplus to be divided, the easier it is for any given increase in one’s share to induce efficient investment incentives. Thus, Evans’s result that option contracts can solve the holdup problem relies on the surplus being large enough. If one relaxes the budget-balance constraint, so that the contract can specify a third party getting a large payout if parties do not follow their equilibrium strategies, this can always be satisfied. But, if one imposes the budget balance constraint (so that payouts to third parties are not allowed), the surplus may not always be large enough for Evans’s option contract to induce efficient investment from both parties.

It is important to note that the equilibrium in Evans (2008) does not satisfy a monotonic sharing rule. That is, in the typical bargaining game, whenever the surplus increases, each party gets a larger payoff. Evans’s renegotiation game does not satisfy this monotonicity property because of the shift from one equilibrium to another in the bargaining game that results from small changes in investment. Thus, because a small increase in surplus can change the equilibrium selected, it can make one party worse off.

This discussion illustrates that when the trading opportunity is durable, whether or not an option contract can solve the holdup problem depends on a critical feature of the bargaining model in the renegotiation game. If rejecting an offer in anticipation of a player (either the offeror or the offeree) exercising her option does not delay trade relative to accepting
the offer, then there is an equilibrium in which option contracts can solve the holdup problem, though this is not necessarily the unique equilibrium. This is a critical feature of the Evans (2008) model. On the other hand, if trade happens sooner when an offer is accepted than when it is rejected even though rejection will be followed by one party exercising her option to trade (as is the case in Shaked and Sutton (1984)), then option contracts cannot, in general, solve the holdup problem. The reason is that the incentive to avoid delay will induce renegotiation even though the option is ‘in the money’. Moreover, if the allowable time for renegotiation is long enough, even if waiting for the other party to exercise her option causes only a very small delay in trading versus accepting an offer, this delay can lead to a renegotiated agreement that leads to a very different allocation of the bargaining surplus than would occur if the option were exercised. Thus, the distortion in investment incentives caused by renegotiation can be quite substantial as long as there is any extra delay caused by rejecting an offer and waiting for the other party to exercise the option as opposed to simply accepting the new offer.

4. Option Contracts in Sequential Investment Settings

While most models of option contracts and holdup focus on the case of simultaneous investment, a few papers have considered whether option contracts can solve the holdup problem in a sequential investment setting. Nöldeke and Schmidt (1998) consider a model of sequential investments and argue that option contracts can be effective in solving the holdup problem even in a situation where investment has some cooperative features. In their model, two parties invest to add value to a physical asset. Thus, total net surplus in their model is \( v(a, b) - a - b \), where \( a \) and \( b \) are the investments of the two parties, \( A \) and \( B \). \( A \) invests at date 1 and \( B \) invests at date 2. At date 0, the parties can write an initial contract allocating ownership of the physical asset. At date 3, the parties can renegotiate this contract to generate the efficient outcome.

They assume that the parties split this surplus with share \( \lambda \) going to \( A \) and share \( 1 - \lambda \) going to \( B \). If the parties cooperate in period 3, they realize the full value from the asset \( v(a, b) \). If \( A \) owns the asset, then he realizes the value \( v(a, \beta b) \) absent cooperation. If \( B \) owns the asset, her disagreement payoff is \( v(\alpha A, B) \); \( \alpha, \beta \in [0, 1] \). That is, if \( A \) owns the asset, then he can only realize part of the value from \( B \)'s investment without \( B \)'s participation. This reflects the fact that some of \( B \)'s investment is human capital investment in how to use the asset. These are simply disagreement points, because in period 3 the parties always agree to cooperate. If \( B \) owns the asset, for example, then to induce \( A \) to cooperate, \( B \) must offer \( A \) a payment of \( \lambda(v(a, b) - v(\alpha A, B)) \), since \( v(a, b) - v(\alpha A, B) \) is the added
surplus to be obtained from cooperation and $\lambda$ is the share of that surplus that $A$ can command by agreeing to cooperate.

If the parties could commit not to renegotiate the ownership structure (though they still bargain to cooperate to obtain the full surplus from the asset), a simple option contract, similar to the one in Nöldeke and Schmidt (1995) will achieve the first best if $B$ always invests efficiently given $A$'s level of investment. The contract has $A$ owning the asset, but $B$ having the option to buy the asset in period 2.5 (after both investments have been made) for a price of $p = \lambda v(a^*, b^*) + (1 - \lambda)v(a^*, b^*) - b$ (where $a^*$ and $b^*$ represent the first-best investment levels). This price equals B’s net payoff from owning the asset, assuming both $A$ and $B$ invest efficiently. Thus, if $a \geq a^*$, then $B$ has a non-negative net payoff from investing efficiently and exercising her option to buy the asset. $A$ will choose $a^*$ to induce $B$ to exercise her option, which gives $A$ the full surplus from the relationship.

Nöldeke and Schmidt argue that this contract is robust to renegotiation. In their model, once investments are sunk, after date 2, the parties always negotiate to an efficient use of the asset regardless of the ownership structure. Thus, the only time renegotiation of the ownership structure contract would occur is between period 1 and 2. Notice, however, that $A$ obtains the entire surplus under the original contract if it invests efficiently in period 1. It cannot do better than this since $B$ can always choose not to invest and get zero. So, $A$ has no incentive to renegotiate at this time unless this is necessary to induce $B$ to exercise its option in period 2.5. Under this contract, if $A$ invests efficiently, this is not necessary. So, there will be no renegotiation and both parties invest efficiently.

Edlin and Hermalin (2000) challenge the idea that option contracts can by themselves solve the holdup problem in a sequential investment setting. They argue that the Nöldeke and Schmidt (1998) option contract is only robust to renegotiation because of the particular timing in their model, timing that Edlin and Hermalin argue is not realistic. That is, Nöldeke and Schmidt assume that the second investor, $B$, must invest prior to deciding whether or not to exercise her option. If, instead, $B$ could delay investing until after letting her option expire, then she would have an incentive to do so. To see this, notice that prior to investing, the strategy of investing and then exercising the option gives $B$ a zero payoff (the price equals her net payoff from owning the asset). Thus, if $B$ can let the option expire and then renegotiate, as long as $B$ gets some surplus from this renegotiation, she will be better off doing so than investing and exercising her option. But, if $B$ does this and obtains some surplus, this means that the price $B$ pays for the

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12 This will be the case if $a$ and $b$ are independent ($\partial^2v/\partial a \partial b = 0$) or if $\alpha = \beta = 1$. 
asset will no longer increase one for one with the increase in value of the asset due to A’s investment. That is, A must share some of the increased surplus it created through its investment. This will lead A to under-invest anticipating this renegotiation; the holdup problem re-emerges.

Nöldeke and Schmidt argue that because the holdup problem makes both A and B worse off ex ante, they have an incentive to write the date 0 option contract so that B’s option never expires. If that is the case, they argue that now B has no credible threat to renegotiate. A will simply refuse any renegotiation offers, knowing that B will invest, and exercise her option in the last period before the value of the asset disappears. As Edlin and Hermalin point out, however, this only works because there is a last period in which B can invest, and if she does not do so, the asset becomes valueless. If delay reduces the value of the asset (or, to put it more generally, the trading opportunity is durable), then the outside option principle (Shaked and Sutton 1984) implies that B’s option is not a binding outside option. Thus, renegotiation should give B some surplus, creating the holdup problem. As the discussion above indicates, however, this is contingent on there being additional delay caused by waiting for an option to be exercised after rejecting an offer relative to accepting that offer.13

5. Conclusion
Whether or not option contracts can solve the holdup problem depends greatly on the details of the renegotiation process. If contracts cannot be renegotiated, then one can use option contracts to solve the holdup problem quite generally.14 If renegotiation is possible, then the effectiveness of option contracts is less clear. When the trading opportunity is not durable (that is, there is a definite point at which the trade in question no longer creates any surplus), then option contracts are also quite effective in solving holdup because it is difficult to credibly threaten not to exercise an in-the-money option before the trading opportunity disappears. This makes renegotiation to the disadvantage of the non-option holder unlikely, since the non-option holder can rely on the option holder to exercise his option absent renegotiation. Since it is this renegotiation that tends to undermine the effectiveness of option contracts, the holdup problem does not appear to be very robust in settings with non-durable trading opportunities.

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13 In the Edlin and Hermalin model, the holdup problem can only be solved if the marginal effect of A’s investment on A’s value without B is at least as great as the marginal effect of this investment on total surplus.

14 See Davis (2006) for a mechanism that might make renegotiation unlikely.
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If the trading opportunity is durable, however, having an in-the-money option does not guarantee that the option holder will exercise this option. She may prefer to delay doing so in order to obtain a more favorable agreement through renegotiation. Whether or not this is possible depends critically on the bargaining model for the renegotiation process. Wickelgren's (2007) critique of the effectiveness of option contracts relies on the assumption that in the renegotiation process, the fastest way for a non-option holder to commence trade is to accept an offer by the option holder. That is, his results rely on the fact that accepting an offer leads to trade faster (even if only a fraction of a second faster) than rejecting an offer – even if one expects the offeror to exercise her option at the earliest opportunity after rejection. If this is the case, then option contracts may often not be able to solve holdup problems. In such cases, a theory of the firm that uses asset ownership as a vehicle for minimizing holdup problems has the potential to be convincing. If, however, accepting an offer need not lead trade to happen any sooner than rejecting an offer and relying on the exercise of the other party’s option to trade, then, as Evans (2008) has shown, option contracts can solve the holdup problem quite generally (though this equilibrium is not unique). In this case, the theory of the firm must be based on something other than using asset ownership to mitigate holdup problems.

Bibliography


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