FORMAL CONTRACTS, RELATIONAL CONTRACTS, AND THE HOLDUP PROBLEM

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Abstract

We study the holdup problem in repeated transactions between a seller and a buyer such that the seller makes relation-specific investments in each period. We show that where, under spot transaction, formal contracts have no value because of the cooperative nature of investment, writing a simple fixed-price contract can be valuable under repeated transactions: There is a range of parameter values in which a higher investment can be implemented only if a formal price contract is written and combined with a relational contract. We also show that there are cases in which not writing a formal contract but entirely relying on a relational contract increases the total surplus of the buyer and the seller. The key condition is how the investment affects the renegotiation price in general, and the alternative-use value in particular.

JEL Code: D23, L14, L22, L24.

Keywords: holdup problem, formal contract, relational contract, cooperative investment, fixed-price contract, relation-specific investment, renegotiation, repeated transactions, long-term relationships.

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1 Introduction

Relation-specific investments often cause holdup problems when contracting is incomplete. Suppose, as an example, that a seller has an opportunity to make an investment which creates more value inside its relationship to a particular buyer than outside. The relation-specific nature of the investment may result in the buyer's opportunistic behavior. Contracts contingent upon investment-related information could protect the seller, but this is often difficult in reality. So, without adequate contractual protection, the seller's anticipation of the buyer's opportunistic behavior results in a less than socially optimal level of investment. The holdup problem has played a central role in the economic analysis of organizations and institutions, and many authors have proposed various organizational interventions, such as vertical integration (Klein et al., 1978; Williamson, 1985), as remedies to the problem.

In the holdup literature, a fundamental driving force of the inefficiency has been the assumption that contracts contingent upon the nature of relation-specific investments are infeasible, which is a realistic assumption in a wide variety of real-world bilateral trade. On the other hand, the courts can often verify delivery of the goods by the seller, and hence simple non-contingent contracts based on product delivery are often feasible. Several articles have recently studied the roles that formal non-contingent price contracts can play in resolving the holdup problem under *spot transaction* (see Section 2 for details).

The present paper offers new perspectives on the roles that such simple non-contingent contracts can play in resolving the holdup problem. In particular, we study *repeated transactions* between a seller and a buyer, and demonstrate that a formal non-contingent price contract can help resolve the holdup problem by mitigating the buyer's temptation to renege on his/her informal agreement with the seller.

In reality, relation-specific investments are often made under long-term and repeated interaction between parties. Coase (1988) pointed out that A.O. Smith, a large independent manufacturer of automobile frames, had invested in expensive equipment that was highly specific to its main customer, such as General Motors, for more than fifty years. Also, Coase (2000) found that prior to the acquisition of Fisher Body by General Motors in 1926, Fisher Body had repeatedly made location-specific investments for General Motors. Regarding Japanese manufacturer-supplier relationships, Asanuma (1989) studied the Japanese automobile and the electric machinery industries and discovered that long-term relationships were more likely to be found in the transaction of intermediate products that require a high degree of relation-specific investments. According to Holmström and Roberts (1998, p.83), "Nucor [the most successful steel maker in the United States over the past 20 years] decided to make a single firm, the David J. Joseph Company (DJJ), its sole supplier of scrap. Total dependence on a single supplier would seem to carry significant hold-up risks, but for more than a decade, this relationship has been working smoothly and successfully."

Despite the important connection between relation-specific investments and long-term relationships, there have been very few theoretical analyses, to the best of our knowledge, that have addressed the holdup problem under infinitely repeated interactions.[1] This might be because, due to a reasoning based on the Folk Theorem, the holdup problem can obviously be resolved under infinitely repeated interactions if the discount factor is high enough. We show, however, that when the discount factor is not high enough, formal fixed-price contracts can play a crucial role in determining the range of the discount factor within which the holdup problem is resolved.

Along with the repeated interaction, another key element of our analysis con-

[1]Note that while several recent papers introduce dynamic structures into the analysis of the holdup problem (Che and Sákovics, 2004; Gul, 2001; Pitchford and Snyder, 2004), they study repeated offers rather than repeated transactions.

cerns the effect of relation-specific investment on the alternative-use value. Most previous theoretical models in the holdup literature assume, implicitly or explicitly, that relation-specific investment *increases* the value of the asset not only within the relationship but also in alternative uses. However, an equally plausible assumption is that the investment *reduces* the value of the asset in alternative uses. For example, if a seller locates its plant adjacent to a buyer, the seller ends up increasing the distance of the plant to alternative buyers. That is, a location-specific investment decreases the value of the asset in alternative uses. Rajan and Zingales (1998), an important exception in the existing literature, argue that relation-specific investments in a physical asset imply, almost by definition, a reduction in the outside value of the asset. We find that this distinction is important when we investigate the value of formal contracting.[2]

In our analysis of the repeated interactions between a seller and a buyer, formal contracting can reduce the buyer's temptation to renege on his/her informal agreements with the seller when the relation-specific investment reduces the renegotiation price. And a necessary condition for the relation-specific investment to reduce the renegotiation price is that the investment reduces the alternative-use value, which is a plausible case as we discussed above. The result is that a formal fixed-price contract, combined with informal agreements sustained by the value of future relationships, can help resolve the holdup problem: A higher investment can be implemented within a wider range of parameter values (e.g., discount factor) with a combination of a formal contract and informal agreements rather than with informal agreements only. In other words, formal contracting can play a complementary role of relaxing the self-enforceability condition for informal agreements. At the same time, however, we also find that there is a certain alternative range of parameterizations in which

[2]Segal and Whinston (2000) find that the value of exclusive contracts depends on whether the outside value of the asset is increasing or decreasing in investment. We assume that exclusive contracts are not feasible because whether or not each party transacts with an alternative outside party is not verifiable.

formal contracting has either no value, or even negative value (in the sense that a higher investment can be implemented only if no formal price contract is written).

The rest of the paper is organized as follows: Section 2 relates the present paper to the existing literature. Section 3 analyzes a simple example in which there are two levels of investment to illustrate our main result and the intuition behind it. Section 4 presents our general model of repeated transactions between a seller and a buyer, in which there are $n+1$ possible levels of investment. Section 5 analyzes the model and finds, among other things, that although investment is purely cooperative, there is a range of parameter values under which the buyer is strictly better off by offering a formal contract. Section 6 first discusses the robustness of our result when uncertainty is introduced, and then considers an extension of our model that incorporates the possibility of vertical integration between the seller and the buyer to demonstrate that writing a formal price contract without integration can still be valuable. Section 7 concludes.

2 Relationship to the Literature

In this section we discuss our contributions to the existing theoretical literature on holdup problems, and to the empirical literature on the relationship between relational governance and formal contracts.

Recently several articles have studied the roles that formal non-contingent price contracts can play in the resolution of the holdup problem under *spot transaction*. Edlin and Reichelstein (1996) considered a bilateral trade relationship in which the seller and the buyer can write a simple contract specifying a fixed trade price and quantity at a future date. The seller then decides how much to invest in a relation-specific asset that lowers the subsequent cost of producing the good. After the investment is made, some state uncertainty, which affects the seller's cost as well as the buyer's valuation, is resolved and observed. The buyer and seller are then free to renegotiate on the contract with exogenously specified bargaining strengths. Edlin and Reichelstein found that a well-designed fixed-price contract can give the seller efficient investment incentives.

Che and Hausch (1999) pointed out that these previous studies were limited by their restriction on the nature of the relation-specific investments; that is, these studies focused on "selfish" investments that benefited the investor (e.g., the seller's investment reduces his production costs). Che and Hausch convincingly argued through a number of examples that "cooperative" investments (e.g., the seller's investment improves the buyer's value of the good) were equally important, although cooperative investments had received little attention in the literature. For instance, the famous General Motors-Fisher Body example deals with Fisher Body's decision of building a plant adjacent to General Motors. Such an arrangement involves a "selfish" as well as a "cooperative" aspect because it not only lowers the seller's shipping costs but also improves its supply reliability.

Che and Hausch's results for cooperative investments are very different from those of Edlin and Reichelstein for selfish investments. They considered a bilateral trade relationship similar to the one analyzed by Edlin and Reichelstein. The most important result of Che and Hausch concerns the case in which the parties cannot credibly commit not to renegotiate the contract. They showed that if investments are sufficiently cooperative, there exists an intermediate range of bargaining shares for which contracting has no value, i.e., contracting offers the parties no advantages over *ex post* negotiation. In particular, contracting has no value for any parameter range if both investments are purely cooperative (that is, the seller's investment benefits the buyer only, and the buyer's investment benefits the seller only).

We contribute to the existing theoretical literature by demonstrating that formal non-contingent price contracts can be valuable even if the relation-specific investment is purely cooperative. In particular, we show that under repeated interaction between parties, a formal price contract can help resolve the holdup problem by mitigating the buyer's temptation to renege on his/her informal agreement with the seller. A necessary condition for this result is that the investment reduces the alternative-use value, which is a plausible case as discussed in the Introduction. In our base model which contains no uncertainty, formal price contracts can be valuable under repeated transactions but are not valuable under spot transaction. In Subsection 6.1 we analyze an extension which contains uncertainty, and find the following results: (i) non-contingent formal contracts can be valuable even under spot transaction;[3] and (ii) if the transaction is repeated infinitely, non-contingent formal contracts are valuable within a broader range of parameter values because of the role that formal contracts can play under repeated transactions in mitigating the buyer's reneging temptation.

Our analysis of informal agreements builds on a general analysis of "relational contracts" by Levin (2003). Baker et al. (1994) and Schmidt and Schnitzer (1995) study how formal contracting affects the self-enforceability of informal agreements. These three papers do not, however, analyze the holdup problem, and hence in their models there is no renegotiation within each period. In our model on the other hand, intra-period renegotiation and the resulting reneging temptation associated with relation-specific investments are crucial features. Baker et al. (2001, 2002), Halonen (2002), and Morita (2001) analyze the holdup problem in infinitely repeated transactions, but their focus is quite different from ours. Baker et al. (2001, 2002) and Halonen (2002) study how asset ownership affects the self-enforceability of relational contracts, and Morita (2001) focuses on the role of partial ownership in resolving the holdup problem under repeated interaction. None of the studies captures the idea that formal contracts can play an important role in reducing reneging temptations under repeated transactions, nor do they identify whether the alternative-use value

[3] A necessary condition for this result, again, is that the relation-specific investment reduces the alternative-use value. This possibility was not considered by Che and Hausch (1999).

is increasing or decreasing in investment as an important factor in determining the value of formal contracting.[4]

The present paper also sheds a new light on recent empirical investigations on the relationship between relational governance and formal contracts. In the empirical literature of transaction cost economics, the majority of previous researchers have studied how several transactional properties (representing asset specificity, uncertainty and transactional frequency) affect an organizational mode, conceptualized by market, hierarchy, or various hybrid and intermediate modes (see e.g. Shelanski and Klein (1995) and Boerner and Macher (2002) for surveys).

Several researchers have recently made an important contribution to this literature by investigating the relationship between relational governance and formal contracts (see e.g. Banerjee and Duflo (2000); Poppo and Zenger (2002); Kalnins and Mayer (2004)). It has often been argued that relational governance and formal contracts are substitutes rather than complements (see Dyer and Singh (1998) and Adler (2001), among others), and that the use of formal contracts may even have undesirable consequences under relational governance (see Macaulay (1963) for an empirical investigation and Bernheim and Whinston (1998) for a theoretical analysis). In contrast, Poppo and Zenger (2002) have recently presented evidence which suggests that relational governance and formal contracts can be complements. In their investigation of informational service outsourcing they found that, controlling for several transactional properties such as asset specificity, increases in the level of relational governance were associated with greater levels of complexity in formal contracts (see Ryall and Sampson (2006) for a related finding).

We contribute to this line of investigation by exploring the relationship between relational governance and formal contracts in the presence of the holdup problem.

[4] Although Baker et al. (2001, 2002) employ a holdup model different from ours, integration in their model and formal contracting in our model play a similar role of eliminating ex post renegotiation opportunities. We will further elaborate the difference between their papers and ours in Subsection 6.2 by introducing asset ownership into our model.

Our analysis identifies whether the alternative-use value is increasing or decreasing in investment as an important factor in determining the value of formal contracts. We find that relational governance and formal contracts can be complements or substitutes, and that the use of formal contacts may even have undesirable consequences. Our analysis indicates that they are complements when the relation-specific investment reduces the renegotiation price, and a necessary condition for this is that the investment reduces the alternative-use value.

3 Example

Setting We can illustrate our main result and the intuition behind it by a simple example. There is a seller and a buyer. In each period, the seller can produce at most one unit of a product, and the buyer purchases at most one unit of the product. In each period the seller has an opportunity to make an investment. The seller chooses either not to invest (0) or to invest (1). The cost for the investment is $a > 0$.

The investment does not affect the seller's production cost, which is normalized to zero, but influences the value of the product for the buyer as well as its alternative-use value. That is, the investment is purely cooperative. Let v_i be the value for the buyer and m_i the alternative-use value if investment is $i = 0, 1$. We assume $\Delta_v \equiv v_1 - v_0 > 0$. Most previous theoretical models in the holdup literature assume, implicitly or explicitly, that $\Delta_m \equiv m_1 - m_0 \geq 0$: Relation-specific investments increase alternative-use values (at least weakly) as well. However, we believe that $m_1 < m_0$ is equally plausible as discussed in the Introduction. For example, suppose that investment 0 represents a general-purpose investment, while 1 represents a relation-specific investment. If the seller makes the general-purpose investment, he can produce the general product that has value m_0 for alternative users. If the seller makes the specific investment, he can produce the product that is customized to the buyer. And if an alternative user purchases the specific product, the user must incur an adjustment cost $c > 0$ in order to convert it to the general product, and hence the effective value of the specific product for the alternative user is $m_0 - c$, which is smaller than m_0.[5] Alternatively, suppose that the seller chooses two kinds of investments, a relation-specific investment (zero or one unit) that only increases the value for the buyer, and a general-purpose investment (zero or one unit) that only increases the alternative-use value. And suppose further that because of various resource constraints, the seller can invest at most one unit of investment. This interpretation of the model corresponds to the case $m_1 < m_0$.[6]

We thus do not assume $\Delta_m \geq 0$ in our analysis but distinguish between $\Delta_m \geq 0$ case and $\Delta_m < 0$ case. We assume (i) $\Delta_v > a > \Delta_m$; and (ii) $v_0 \geq \max\{m_1, m_0\}$. These two assumptions imply that it is efficient for the seller to invest and trade with the buyer, but the investment cannot be realized under spot transaction.

Each period starts with the buyer's decision to offer a price contract. We make a standard assumption that all the relevant variables are observable but unverifiable to both the seller and the buyer, while delivery and transfer are verifiable, and hence a simple price contract can be written and enforced. The buyer's offer is a take-it-or-leave-it offer, and the price contract can be a formal contract, an informal agreement, or a combination of these two. Then, if the price contract contains a formal contract, the seller decides whether or not to sign it. Second, the seller chooses whether or not to invest. Third, the buyer and the seller engage in renegotiation, in which the buyer makes a take-it-or-leave-it price offer to purchase a product from the seller. Finally, the seller produces a product and sells it to the buyer or in the outside market.

Spot transaction We first analyze the benchmark case of spot transaction where the seller and the buyer meet only once, or do not use history-dependent strategies. We solve for subgame perfect equilibria of the stage game. The buyer's renegotiation

[5] See also Rajan and Zingales (1998).

[6] See Cai (2003) who studies such a multi-dimensional investment model in which increasing relation-specific investment reduces general-purpose investment and hence reduces the outside value.

price offer is $p_i = m_i$ if investment is $i = 0, 1$. Since $m_0 - (m_1 - a) = -\Delta_m + a > 0$, the seller chooses not to invest (underinvestment) and hence the holdup problem arises.

Formal contracts do not help under spot transaction. Consider a simple fixed-price contract such as "pay price p for the delivery of the product." It is enforced with a specific performance damage clause, which is a standard legal breach remedy often applied in practice: when one party sues for specific performance, the court orders the second party to perform exactly what the contract specifies. Such a contract can resolve the holdup problem if the investment is purely "selfish" as in Edlin and Reichelstein (1996). However, when investment is purely "cooperative" as in our model, the seller chooses not to invest in order to save the investment cost a, and hence underinvestment persists.[7] In fact Che and Hausch (1999) showed, in a general setup, that if the parties cannot commit themselves not to renegotiate, they cannot do better by writing a formal contract, along with any communication mechanism, than having no contract.

Repeated transactions without a formal contract We now show that this result for spot transaction changes dramatically under repeated transactions. We consider infinitely repeated interaction with perfect monitoring between the seller and the buyer with the common discount factor $\delta \in (0, 1)$, and solve for subgame perfect equilibria of the infinitely repeated game that can implement the efficient outcome (investment by the seller). We focus on trigger-strategy equilibria, in which after either party reneges, both the seller and the buyer follow the static equilibrium strategies under spot transaction forever from the next period on. We assume without loss of generality that they do not write a formal contract under the static equilibrium.

Consider the following strategies under which the buyer does not offer a formal

[7] Note that the price contract cannot be contingent on investment that is unverifiable.

contract. At the beginning of each period, the buyer promises to pay $\overline{b} = m_0 + a$ conditional on the seller's investment. And the buyer actually pays $\overline{b}$ if the seller invests. If the seller chooses no investment, the buyer offers $p_0 = m_0$ at the renegotiation stage in the same period, and then reverts to the static equilibrium strategy from the next period on. The seller chooses to invest if the buyer actually paid $\overline{b}$ in the previous periods. Otherwise, he continues to choose not to invest forever.

If the seller believes that the buyer follows the strategy given above, then investment results in payoff $\overline{b} - a = m_0$ in each period, while no investment yields payoff $p_0 = m_0$. The seller thus has no incentive to deviate, and chooses to invest. However, the buyer may have an incentive to cheat. Suppose the seller invests in a given period. The buyer will be better off in that period by deviating from paying $\overline{b}$ and instead offering $p_1 = m_1$, which the seller will accept. The buyer's reneging temptation is thus $\overline{b} - m_1 = a - \Delta_m > 0$. His/her future loss from this deviation is given by

$$\frac{\delta}{1-\delta}\left[(v_1 - \overline{b}) - (v_0 - m_0)\right] = \frac{\delta}{1-\delta}\left(\Delta_v - a\right).$$

The buyer honors the promise if and only if

$$a - \Delta_m \leq \frac{\delta}{1-\delta}\left(\Delta_v - a\right), \tag{1}$$

that is, if the reneging temptation does not exceed the future loss.

Repeated transactions with a formal contract Next, suppose that in each period the buyer offers a formal fixed-price contract. And we allow the buyer to combine the formal contract with an informal promise. We thus consider the following strategies. At the beginning of each period, the buyer writes a formal price contract p to be paid for delivery of the product, and in addition, promises to pay a bonus b if the seller invests. If the seller does not invest, the buyer will revert to the static equilibrium strategy from the next period on. The seller chooses to invest if the buyer actually offers contract p and pays b in the previous periods. Otherwise, he/she continues to choose no investment forever.

The important difference from the no-formal-contract scenario concerns what happens when the buyer reneges on the promised bonus b after the investment is made by the seller, and what happens when the seller does not invest. In both cases, although the buyer does not pay the bonus b, he/she is forced to pay p by the specific performance damage clause, and the buyer and the seller cannot agree on a renegotiation price because at least one party must prefer the formal price p. Keeping this difference in mind, we derive the conditions for the efficient outcome to be implemented.

If the seller believes that the buyer follows the strategy given above, then investment results in payoff $p + b - a$ in each period, while no investment yields payoff p in the current period, and m_0 from the next period on. The seller thus chooses to invest if his/her reneging temptation $p - (p + b - a) = a - b$ is at most as high as the future loss:

$$a - b \leq \frac{\delta}{1-\delta}(p + b - a - m_0) \tag{2}$$

Suppose next that the seller invests in a given period. The buyer's reneging temptation is $p + b - p = b$. His/her future loss from cheating is given by

$$\frac{\delta}{1-\delta}\left[(v_1 - p - b) - (v_0 - m_0)\right] = \frac{\delta}{1-\delta}\left(\Delta_v - p - b + m_0\right).$$

The buyer thus honors the promise if and only if

$$b \leq \frac{\delta}{1-\delta}\left(\Delta_v - p - b + m_0\right). \tag{3}$$

Summing inequalities (2) and (3) yields a necessary condition for the efficient outcome to be implemented by a combination of a formal contract and an informal promise:

$$a \leq \frac{\delta}{1-\delta}\left(\Delta_v - a\right). \tag{4}$$

Conversely, if (4) holds, the buyer can find a self-enforcing contract (p, b) that implements the efficient outcome. The best combination for the buyer is to leave no rent to the seller, (p, b) satisfying $p + b = m_0 + a$. Substituting this into (2) yields $b \geq a$, and hence $(p, b) = (m_0, a)$ is one best combination for the buyer: the seller chooses to invest without any rent because the informal bonus contingent upon investment just covers the investment cost a.

Comparison We now compare the result under no formal contract with that under a fixed-price contract. Since the buyer can extract all the surplus if an efficient equilibrium exists, the comparison is in terms of the condition for its existence, that is, between (1) and (4). First suppose $\Delta_m < 0$. Then (1) implies (4) but the reverse is not true. This implies that the buyer is never worse off by writing an appropriate formal contract, and that, although investment is purely cooperative and hence writing a formal contract does not help at all under spot transaction, there is a range of parameter values under which the buyer is strictly better off by offering a formal contract. That is, under a certain range of parameter values, the buyer cannot induce the seller to invest without a well-designed formal price contract.

The intuition here goes as follows. In order to induce the seller to invest, the buyer offers an informal but self-enforcing pay contingent on the seller's investment. This role is played by b in either case. The difference is in the reneging temptation. Since all the surplus goes to the buyer, we can restrict our attention to the buyer's reneging temptation. When no formal contract is written, the buyer can hold the seller up by not paying $\overline{b} = m_0 + a$ and instead offering a renegotiation price $m_1 = m_0 + \Delta_m$. The buyer's reneging temptation here is $\overline{b} - m_1 = a - \Delta_m$. On the other hand, when a formal price contract $p = m_0$ is written, the buyer cannot renegotiate the price down from m_0 to $m_1 = m_0 + \Delta_m$ (recall that we consider $\Delta_m < 0$ case here). This means that the buyer can effectively reduce his/her reneging temptation from $a - \Delta_m$ to a by writing the formal fixed-price contract.

Can the self-enforceability of the contract (p, b) be enhanced by further reducing the buyer's reneging temptation from a? The answer is no, and the logic is as follows. Suppose that the buyer reduces b from a to $a - \epsilon$, which decreases his/her own reneging temptation by ϵ. However, this reduction of the bonus increases the seller's reneging temptation. That is, the left-hand side of (2) is now positive ϵ, and hence the buyer must give per period rent $\epsilon(1 - \delta)/\delta$ to the seller to prevent the seller's temptation of no investment. This in turn means that the present discounted value of the buyer's future loss from reneging (the right-hand side of (3)) must also be reduced by ϵ. The result is that the self-enforceability of the contract cannot be enhanced by reducing the buyer's reneging temptation from a.

Next suppose $\Delta_m \geq 0$. In this case we find that the buyer is never better off by writing a formal contract, and if $\Delta_m > 0$, there is a range of parameter values under which the buyer is strictly worse off by offering a formal price contract. To see why, suppose that the buyer offers a formal fixed-price contract. As shown above, the best combination for the buyer is (p, b) satisfying $p + b = m_0 + a$ and $b \geq a$, and hence the buyer's reneging temptation is at least a. On the other hand, when no formal contract is written, as shown above, the buyer's reneging temptation is $a - \Delta_m$, which is less than a given $\Delta_m > 0$.

In the subsequent sections, we show the optimality of writing a formal contract in repeated transactions more generally. We show when it helps to combine a formal contract with an informal agreement, and when an informal promise is sufficient.

4 Model

We consider repeated transactions between an upstream party (seller) and a downstream party (buyer). In each period, the seller chooses an investment level $a \in A$ by incurring private cost $d(a)$. We assume that there are $n+1$ possible investment levels $a_0, a_1, \ldots, a_n$ that are measured in terms of the investment costs, and hence $d(a_i) = a_i$, and we assume $0 \leq a_0 < a_1 < \cdots < a_n$.

The seller's investment affects (i) the value of the seller's product for the buyer and (ii) the alternative-use value of the product. When the seller's investment is a_i, let v_i be the value for the buyer and m_i be the alternative-use value, which we assume for simplicity to be equal to the price the seller can sell to an alternative user.[8] The buyer's payoff is zero when the seller does not sell the product to him/her. For simplicity, we assume that at most one unit of the product is traded, and the production cost is normalized to zero. We assume v_i is strictly increasing in i, $v_0 \geq \max_i m_i$, and $v_i > a_i$ for all i, so that it is always efficient for the seller and the buyer to trade. Denote the efficient investment by a^*: $a^* = a_j$ where $j = \arg\max_i (v_i - a_i)$. We assume a^* is unique and $a^* > a_0$.

The alternative-use value m_i may be increasing or decreasing (it can be non-monotonic as well). We however follow the holdup literature by assuming that investment affects v_i at least as much as m_i at margins:

$$v_i - v_{i-1} \geq m_i - m_{i-1} \quad \text{for } i = 1, \ldots, n. \tag{5}$$

We assume that a_i, v_i, and m_i are observable to both parties but unverifiable, while delivery of the product and transfer payments are verifiable, and hence a fixed-price contract is feasible and enforced with a specific performance damage clause.

In each period, the timing is as follows. First, the seller and the buyer may sign

[8]The effects of introducing uncertainty will be discussed in Subsection 6.1.

a contract. Second, the seller chooses investment. Third, the seller and the buyer (re)negotiate a price. We assume that the parties cannot commit themselves not to renegotiate, and the renegotiation price is determined by the generalized Nash bargaining solution. Let $\alpha \in [0, 1)$ be the seller's share of the gain from trade, and hence the buyer's share is $1 - \alpha$. Fourth, the seller produces and sells the product to the buyer at the agreed price or in the outside market.

5 Analysis

5.1 Spot Transaction

When the seller and the buyer meet only once, or they do not use history dependent strategies, a standard holdup problem can arise. Suppose that no formal price contract is written at the beginning. Since trade is always efficient, the seller and the buyer decide to trade and negotiate the price after the seller makes an investment. When the seller chooses a_i, the gain from trade is $v_i - m_i$, and hence the renegotiation price p_i satisfies

$$p_i = m_i + \alpha(v_i - m_i) = \alpha v_i + (1 - \alpha)m_i.$$

The seller's payoff is thus

$$p_i - a_i = \alpha v_i + (1 - \alpha)m_i - a_i.$$

The seller chooses the investment that maximizes $p_i - a_i$. Let a^o be the optimal investment under spot transaction: $a^o = a_j$ where $j = \arg\max_i(p_i - a_i)$.

In this setup it is easy to show that the seller does not overinvest.

Proposition 1 If no formal price contract is written at the beginning, the seller does not overinvest under spot transaction: $a^* \geq a^o$.

Proof Let $a^* = a_j$ and $a^o = a_i$, and suppose instead $a_j < a_i$. Since a_j is uniquely efficient, $v_j - a_j > v_i - a_i$, or

$$a_i - a_j > v_i - v_j$$

holds. On the other hand, since a_i is optimal under spot transaction, $p_i - a_i \geq p_j - a_j$ holds. Then, by $\alpha < 1$, $a_i > a_j$, and (5),

$$a_i - a_j \leq \alpha(v_i - v_j) + (1 - \alpha)(m_i - m_j) \leq v_i - v_j$$

must hold, which is a contradiction. **Q.E.D.**

Since the seller cannot reap all the returns from the investment, his/her optimal investment choice is at most a^*. To make the analysis interesting, we hereafter assume $a^* > a^o$: If $a^* = a_j$, there exists $i < j$ such that

$$a_j - a_i > \alpha(v_j - v_i) + (1 - \alpha)(m_j - m_i). \tag{6}$$

When $a^o = a_i$, define the seller's payoff, the buyer's payoff, and the joint surplus, respectively, as follows:

$$\pi_S^o = w + p_i - a_i, \quad \pi_B^o = v_i - w - p_i, \quad \pi^o = \pi_S^o + \pi_B^o = v_i - a_i$$

where w is a fixed transfer paid from the buyer to the seller at the beginning of the period (negative w implies payment from the seller to the buyer) that serves the distribution purpose only.

5.2 Relational Contract

We now consider the case in which the seller and the buyer engage in infinitely repeated transactions, with the common discount factor δ. Suppose that at the beginning of each period the seller and the buyer agree on an informal compensation plan, with the seller's promising investment a_j. In this subsection, we assume no formal price contract is written. The effects of writing a formal price contract are analyzed in the next subsection. The informal compensation plan consists of $(w, b_0, \ldots, b_n)$, where w is paid from the buyer to the seller at the beginning of each period, and b_i is a price paid by the buyer when the seller's investment is a_i (b_i may be negative, in which case it is a penalty paid by the seller). A *relational contract* is a complete plan for the relationship, describing the compensation plan and the seller's investment for every period and history. We study trigger-strategy equilibria in which if either party reneges on the payment or investment, they renegotiate to determine the price, and, from the next period on, they revert to spot transaction. The *optimal contract* is the one that maximizes the joint surplus.

We focus on *stationary contracts* under which in every period the parties agree on the same compensation plan and the seller chooses the same investment on the equilibrium path. Our focus on stationary contracts is without loss of generality, due to Levin (2003): if an optimal contract exists, there are optimal stationary contracts.[9] And a similar logic can be applied to show that we can further restrict our attention to contracts that provide the seller's investment incentives with discretionary payments alone.

Since a relational contract is in general contingent on the seller's investment which is observable but unverifiable, it must satisfy conditions under which it is neither party's interest to renege on the contract: it must be *self-enforcing*, i.e.,

[9] Although Levin (2003) does not analyze a case where the parties engage in renegotiation in each period, it is straightforward to generalize his results to such a situation.

a subgame perfect equilibrium of the repeated game. We obtain conditions under which there exists a self-enforcing (stationary) relational contract that implements a given investment a_j attaining a higher total surplus than a^o.

First, the seller's incentive compatibility constraints are given as follows.

$$b_j - b_i \geq a_j - a_i \quad \text{for all } i \neq j \tag{IC}$$

Note that future payoffs do not appear in the constraints.

Second, if the seller chooses a_i and the buyer does not pay the discretionary price b_i, then there is renegotiation and the price to be paid is $p_i = \alpha v_i + (1-\alpha) m_i$. The reneging temptation of the buyer is thus $b_i - p_i$. He/she will then lose his/her future per period gain $v_j - w - b_j - \pi_B^o$. The buyer therefore honors the agreement if and only if

$$b_i - p_i \leq \frac{\delta}{1-\delta}\left(v_j - w - b_j - \pi_B^o\right)$$

holds for all i. The equivalent condition is given as follows.

$$\max_i \left(b_i - p_i\right) \leq \frac{\delta}{1-\delta}\left(v_j - w - b_j - \pi_B^o\right). \tag{7}$$

Third, if the seller chooses a_i and does not pay the penalty $-b_i$, he/she is instead paid the renegotiation price p_i. The seller's reneging temptation is hence $-(b_i - p_i)$. His/her future per period loss is $w + b_j - a_j - \pi_S^o$. The seller therefore honors the agreement if and only if

$$-\left(b_i - p_i\right) \leq \frac{\delta}{1-\delta}\left(w + b_j - a_j - \pi_S^o\right)$$

holds for all i. This condition is equivalent to

$$-\min_i \left(b_i - p_i\right) \leq \frac{\delta}{1-\delta}\left(w + b_j - a_j - \pi_S^o\right). \tag{8}$$

Combining (7) and (8) yields a single necessary condition:

$$\max_i (b_i - p_i) - \min_i (b_i - p_i) \leq \frac{\delta}{1-\delta} (\pi_j - \pi^o) \tag{9}$$

where $\pi_j = v_j - a_j$ is the total surplus under investment a_j. And (IC) and (9) are also sufficient for investment a_j to be implemented: one can find an appropriate w such that (7), (8), and the parties' participation constraints are satisfied.

Now suppose $a^o = a_k$, and a_j can be implemented. There exists a compensation plan $(b_0, \ldots, b_n)$ satisfying (IC) and (9). Since $b_j - p_j \leq \max_i(b_i - p_i)$ and $b_k - p_k \geq \min_i(b_i - p_i)$,

$$\max_i (b_i - p_i) - \min_i (b_i - p_i) \geq (b_j - p_j) - (b_k - p_k)$$

holds. Therefore by (IC) and (9), the following condition follows.

$$(a_j - a_k) - (p_j - p_k) \leq \frac{\delta}{1-\delta} (\pi_j - \pi^o) \,. \tag{DE-NC}$$

The next proposition shows that condition (DE-NC) is necessary and sufficient for the implementation of a_j.

Proposition 2 Suppose no formal price contract is written and $a^o = a_k$. Investment a_j satisfying $\pi_j > \pi_k$ can be implemented by a relational contract if and only if (DE-NC) holds.

Proof We only need to prove the sufficiency part. Supposing (DE-NC), we construct a compensation plan that satisfies (IC) and (9). Let b_k be given arbitrarily and define $b_0, \ldots, b_n$ as follows:[10]

$$\begin{aligned} b_j - b_k &= a_j - a_k \\ b_i - b_k &= p_i - p_k, \quad \text{for all } i \neq j \end{aligned} \tag{10}$$

By definition, (IC) is satisfied for $i = k$. And for $i \neq k$, (IC) holds because

$$\begin{aligned} (b_j - b_i) - (a_j - a_i) &= (b_j - b_k) - (a_j - a_k) + (b_k - b_i) - (a_k - a_i) \\ &= (b_k - b_i) - (a_k - a_i) \\ &= (p_k - p_i) - (a_k - a_i) \geq 0 \end{aligned}$$

where the second and the third equalities follow from the definition of b_i and b_k, and the inequality holds because $a^o = a_k$.

We next show $\max_i(b_i - p_i) = b_j - p_j$. First, for $i = k$,

$$\begin{aligned} (b_j - p_j) - (b_k - p_k) &= (p_k - p_j) - (b_k - b_j) \\ &= (p_k - p_j) - (a_k - a_j) \geq 0 \end{aligned}$$

by the definition of b_j and b_k, and $a^o = a_k$. Next, by the definition of b_i and b_k, for $i \neq j, k$,

$$(b_i - p_i) - (b_k - p_k) = (b_i - b_k) - (p_i - p_k) = 0 \tag{11}$$

and hence $(b_j - p_j) - (b_i - p_i) = (b_j - p_j) - (b_k - p_k) \geq 0$.

Furthermore, (11) yields $\min_i(b_i - p_i) = b_k - p_k$. We therefore obtain

$$\begin{aligned} \max_i (b_i - p_i) - \min_i (b_i - p_i) &= (b_j - p_j) - (b_k - p_k) \\ &= (a_j - a_k) - (p_j - p_k) \end{aligned}$$

[10] The fixed payment w is only used to guarantee that (7), (8), and the participation constraints are satisfied.

(9) now follows from (DE-NC). **Q.E.D.**

Condition (DE-NC) is the necessary and sufficient condition for a_j to be implemented without any formal price contract under repeated transactions. Note that the condition only depends on the parameters under the investment which is to be implemented (a_j) and the investment which is most preferred by the seller under spot transaction ($a^o = a_k$). Intuitively, the seller's incentive compatibility constraints are binding at $a_i = a_k$, and the buyer must pay the seller sufficiently higher ($a_j - a_k$) for investment a_j than for a_k. However, the higher pay for a_j results in reneging temptations for both parties. The buyer faces the temptation not to pay bonus b_j but to pay the renegotiation price p_j. The seller faces the temptation to choose a_k, and not to pay penalty $-b_k$ but to receive p_k. The total reneging temptation is thus equal to the left-hand side of (DE-NC), which must be at most as large as the total future loss.

Note that the right-hand side of (9) or (DE-NC) does not depend on the compensation plan. There is hence no compensation plan that makes the total reneging temptation given in the left-hand side of (9) smaller than the left-hand side of (DE-NC). Therefore, the compensation plan that satisfies (10) in the proof of the proposition minimizes the left-hand side of (9), and in this sense, it is an optimal contract implementing a given investment a_j.

5.3 Formal Price Contract

Next, suppose that at the beginning of each period the buyer and the seller sign a formal fixed-price contract enforced with a specific performance damage clause.[11] Since in our model the investment is purely cooperative, fixed-price contracts perform

[11] Our focus on fixed-price contracts as a form of formal contracts can be justified by our objective to show that even writing a simple fixed-price formal contract can help mitigate the holdup problem under repeated transactions while it does not under spot transaction (Proposition 4 (a)). See footnote 14 for a related discussion.

at most as well as no contract under spot transaction. To see this, note that no renegotiation occurs since trade is always efficient. And since the seller is sure to receive the contractually specified fixed price, he/she has an incentive to minimize the investment cost by choosing a_0. The seller can in fact save costs since the court cannot observe this deviation.[12] The outcome is worse than the no contract case where although the seller underinvests, he/she may choose an investment higher than a_0.[13]

The story is different for repeated transactions. We again focus on stationary contracts that provide the seller's incentives with payments only. Let p be the price specified in the formal fixed-price contract at the beginning of each period. In addition, the parties can also agree on a compensation plan $(w, b_0, \ldots, b_n)$. Note that if either party reneges on payments, no renegotiation arises because price p is enforced. From the next period on, the parties revert to spot transaction in which we assume no formal price contract is written since writing a formal contract is weakly dominated. We derive conditions for the self-enforcing relational contract implementing a given investment a_j to exist.

The seller's incentive compatibility constraints do not change from those under no formal price contract, and are given by (IC). The buyer honors the agreement if and only if

$$b_i \leq \frac{\delta}{1-\delta}\left(v_j - p - w - b_j - \pi_B^o\right)$$

for all i, which is equivalent to

$$\max_i b_i \leq \frac{\delta}{1-\delta}\left(v_j - p - w - b_j - \pi_B^o\right).$$

Note that after reneging, the seller and the buyer do not agree to renegotiate the

[12]See footnote 14 for other forms of formal contracts.
[13]It is easy to show that the total surplus under $a^o = a_k$ is at least as large as that under a_0.

fixed price p. Similarly, the seller honors the agreement if and only if

$$-b_i \leq \frac{\delta}{1-\delta}\left(p + w + b_j - a_j - \pi_S^o\right)$$

for all i, which is equivalent to

$$-\min_i b_i \leq \frac{\delta}{1-\delta}\left(p + w + b_j - a_j - \pi_S^o\right).$$

Combining these conditions yields

$$\max_i b_i - \min_i b_i \leq \frac{\delta}{1-\delta}\left(\pi_j - \pi^o\right) \tag{12}$$

By further combining (IC) and (12), we obtain the following result.

Proposition 3 Investment a_j satisfying $\pi_j > \pi^o$ can be implemented by a combination of a formal price contract and a relational contract if and only if the following condition holds.

$$a_j - a_0 \leq \frac{\delta}{1-\delta}\left(\pi_j - \pi^o\right) \tag{DE-FP}$$

Proof The necessity part follows from $\max_i b_i - \min_i b_i \geq b_j - b_0$ and (IC) for $i = 0$. To prove the sufficiency part, suppose (DE-FP) holds. And for an arbitrary b_0 define $b_1, \ldots, b_n$ by $b_j - b_0 = a_j - a_0$ and $b_i = b_0$ for all $i > 0$ and $i \neq j$. Since $b_j - a_j = b_0 - a_0 > b_i - a_i$ for all $i > 0$ and $i \neq j$, (IC) is satisfied. And (12) follows from (DE-FP) because

$$\max_i b_i - \min_i b_i = b_j - b_0 = a_j - a_0.$$

Q.E.D.

5.4 Comparison

We can analyze the value of writing a formal fixed-price contract in repeated transactions by comparing two conditions, (DE-NC) for the case of no formal price contract, and (DE-FP) for the case of writing a formal price contract.

The conditions differ only in terms of the reneging temptations given on the left-hand sides, and the reneging temptations are different in two respects. One difference is captured by the term $-(p_j - p_k)$, which appears in (DE-NC) but does not appear in (DE-FP). The difference arises because, after reneging, the seller and the buyer renegotiate the price to trade the product under no formal contract, while no renegotiation occurs under formal price contract because price p is enforced. Hence renegotiation affects the reneging temptation only when no formal contract is written.

The other difference, captured by the term $(a_j - a_k)$ in (DE-NC) and the term $(a_j - a_0)$ in (DE-FP), arises because the seller's optimal investment under spot transaction may be different. It is always a_0 under a formal fixed-price contract, while the optimal investment under no formal contract, a^o ($\equiv a_k$), may be higher than a_0. Under no formal price contract, the seller may choose an investment higher than the least costly level because the investment affects the renegotiation price. When no formal contract is written, there is renegotiation, and the renegotiation price depends on the seller's share (α), the value for the buyer (v_i), and the alternative-use value (m_i). Since the value for the buyer is increasing in investment, it provides the seller with an incentive to choose higher investment if the seller's share is positive. Furthermore, if the alternative-use value increases with investment, it provides an additional incentive to increase investment, although the effect is not as large as that of the value for the buyer because of (5). And even if the alternative-use value is decreasing, the marginal benefit of investment for the buyer captured by the seller may be so large that the seller is induced to choose $a^o > a_0$.

The following comparative result is now immediate.

Proposition 4 Suppose $a^o = a_k$ and consider the implementation of a_j satisfying $\pi_j > \pi^o$.

(a) Suppose $(a_k - a_0) + (p_j - p_k) < 0$ holds. If a_j can be implemented under repeated transactions without any formal contract, the same investment can be implemented under repeated transactions with an appropriate formal fixed-price contract. And there is a range of parameter values in which a_j can be implemented only if a formal price contract is written.

(b) Suppose $(a_k - a_0) + (p_j - p_k) > 0$ holds. If a_j can be implemented under repeated transactions with a formal fixed-price contract, the same investment can be implemented under repeated transactions without any formal price contract. And there is a range of parameter values in which a_j can be implemented only if no formal price contract is written.

Proposition 4 (a) shows that in contrast to a well-known result in the case of spot transaction that "formal contracting has no value," a simple fixed-price contract, combined with an informal compensation plan, can help mitigate the holdup problem under repeated transactions. Condition $(a_k - a_0) + (p_j - p_k) < 0$ reflects two sources of differences in the reneging temptation explained above. To better understand the condition, we first suppose $a^o = a_k = a_0$: under spot transaction, the seller faces no incentive to invest higher than the least costly investment. This holds if

$$\alpha(v_i - v_0) + (1 - \alpha)(m_i - m_0) < a_i - a_0, \quad \text{for all } i > 0. \tag{13}$$

Then the condition $(a_k - a_0) + (p_j - p_k) < 0$ is equivalent to $p_j < p_0$. By eliminating the effect of the renegotiation price on the reneging temptation, a well-designed formal price contract reduces the reneging temptation from $(a_j - a_0) - (p_j - p_0)$ to

$a_j - a_0$. Therefore, there is a range of parameter values in which (DE-FP) holds while (DE-NC) does not.

Since the renegotiation price is determined by the generalized Nash bargaining solution, $p_j - p_0 = \alpha(v_j - v_0) + (1-\alpha)(m_j - m_0)$. A necessary condition for $p_j - p_0 < 0$ is thus $m_j < m_0$: the alternative-use value must be lower under the higher investment a_j than under a_0. We have already argued in the previous sections that this is plausible under some settings. Under repeated transactions, this marginal change of the alternative-use value brings a new negative effect of raising the total reneging temptation under no formal contract. The fixed-price contract can eliminate this negative "market incentive" and hence can be valuable.

On the other hand, Proposition 4 (b) shows that if the marginal effect of investment on the alternative-use value is positive, the fixed-price contract has no value even under repeated interactions.[14] Furthermore, eliminating such a positive "market incentive" by writing a fixed-price contract may reduce the total surplus

[14]To explore the robustness of our results, we considered two other well-studied forms of formal contracts. First, consider a formal contract that specifies an option for the buyer to purchase the product at a prespecified price p. It is well known that under spot transaction, such an option contract resolves the holdup problem if the parties could commit not to renegotiate. In our model with $a^* = a_j$ and $a^o = a_k$, setting price $p^* = v_j$ does the job. To see this, first note that observing investment a_i, the buyer exercises the option and obtains payoff $v_i - p^*$ if $a_i \geq a_j$, and rejects the product (payoff zero) if $a_i < a_j$. Expecting this response, the seller prefers to choose a_j and obtain payoff $p^* - a_j$ than to choose $a_i < a_j$ with payoff $m_i - a_i$. However, since they cannot commit not to renegotiate, the buyer does not exercise the option and instead settles with the renegotiation price p_i if $p^* > p_i$. The seller therefore chooses a_i that maximizes $\min(p^*, p_i) - a_i$, which cannot attain a total surplus higher than $v_k - a_k$. Although it is true that repeated interaction enables the parties to commit themselves not to renegotiate, the reneging temptation must be low enough to make such a commitment credible. And since reneging leads to renegotiation, the necessary and sufficient condition for a_j to be implemented turns out to be the same as (DE-NC), the condition under no formal contract. Formal option contracts are hence of no value even under repeated transactions.

As another well-studied contract, consider the following contract (p^1, p^0), where p^1 is the price the buyer has to pay if he/she agrees to buy the product, while p^0 is the price that he/she pays if he/she decides not to buy it (a liquidated damage measure). Again, this contract can resolve the holdup problem if no renegotiation is allowed. Since this contract is essentially equivalent to the option contract with $p^1 - p^0$ being the option price, it is susceptible to renegotiation under spot transaction, and it has no value under repeated transactions.

In summary, we have found that these more complicated (but common) forms of formal contracts have no value even under repeated transactions. Note that this finding does not affect the value of Proposition 4 (a), because the point here is that even writing a simple fixed-price formal contract can help mitigate the holdup problem under repeated transactions, but it does not under spot transaction.

under repeated transactions. Note that the result follows even though the marginal benefit on the alternative-use value is not large enough to increase the seller's investment from the least costly level under a spot transaction. The formal price contract has a negative value because of the increasing reneging temptation under repeated transactions.[15]

The two-investment example in Section 3 corresponds to $\alpha = 0$ (the buyer's take-it-or-leave-it offer), and hence the sign of $\Delta_m = m_1 - m_0$ is the same as that of $p_1 - p_0$: whether or not the alternative-use value is increasing or decreasing fully determines the value of writing a formal contract. In more general settings analyzed here, not only the marginal effect of investment on the alternative-use value but also the marginal effect on the value for the buyer matters.

We have so far developed intuition under assumption (13) so that $a^o = a_0$, in order to clarify how crucial is the marginal effect of investment on the renegotiation price, and in particular the alternative-use value, for the value of writing a formal price contract. Now consider a more general case of $a^o = a_k \geq a_0$. Suppose the investment incentive through renegotiation is so strong that the seller is induced to choose an investment higher than the least costly level even under spot transaction ($a_k > a_0$). This advantage of not writing a formal price contract under spot transaction plays an additional beneficial role of reducing the reneging temptation under repeated transactions, because the incentive necessary to induce the seller to choose a_j decreases from $a_j - a_0$ to $a_j - a_k$. The condition for writing a formal price contract to be valuable is now $(a_k - a_0) + (p_j - p_k) < 0$: the value of writing a formal contract thus may not be positive even if the renegotiation price is decreasing ($p_j < p_k$).

[15] This result has a flavor of an endogenous incomplete contract. Bernheim and Whinston (1998) show that parties may optimally leave some verifiable aspects of performance unspecified ("strategic ambiguity") in order to alter the set of feasible self-enforcing informal agreements. Not writing a formal contract in our model may be classified as one form of strategic ambiguity, although the underlying models and logics are different. While we model the dynamic contracting problem in the context of infinitely repeated interaction and emphasize the effect on the alternative-use values, they consider two-period dynamic models with or without intertemporal payoff linkages.

However, writing a formal price contract can still be beneficial if the positive effect of decreasing the buyer's reneging temptation by $-(p_j - p_k)$ dominates the negative effect of increasing the seller's reneging temptation by $a_k - a_0$.

Example In this example, there are three feasible investments a_0, a_1, a_2 with $a_0 = 0$, $a_1 = \Delta_a > 0$, and $a_2 = 2\Delta_a$: the investment cost increases linearly. Furthermore, $\Delta_v \equiv v_2 - v_1 = v_1 - v_0 > \Delta_a$, so that the value of the product for the buyer increases linearly as well. The inequality implies that the efficient investment is $a^* = a_2$. As for the alternative-use values, we assume $m_0 < m_1 > m_2$ satisfying $p_1 - p_0 > \Delta_a$ and $-(p_2 - p_1) > \Delta_a$. The seller then chooses $a^o = a_1$ under spot transaction without a formal price contract.

Consider the implementation of $a^* = a_2$. Conditions (DE-NC) and (DE-FP) are rewritten as (14) and (15), respectively:

$$\Delta_a - (p_2 - p_1) \leq \frac{\delta}{1-\delta}(\pi_2 - \pi^o) \tag{14}$$

$$2\Delta_a \leq \frac{\delta}{1-\delta}(\pi_2 - \pi^o) \tag{15}$$

Since $\Delta_a < p_1 - p_2$, the left-hand side of (15) is smaller than that of (14). That is, writing a fixed-price contract is valuable under repeated transactions, despite a strictly negative value under spot transaction.

6 Extensions

6.1 Uncertainty

In the main model analyzed in the previous sections there is no random factor. In this subsection we introduce uncertainty into our model and illustrate that non-contingent formal contracts can be valuable even under spot transaction when the value of investment for alternative use is decreasing in a relation-specific investment.

We also show that, if the transaction is repeated infinitely, non-contingent formal contracts can be valuable under a broader range of parameter values because of the role that formal contracts can play under repeated transactions in mitigating the parties' reneging temptation.

To these purposes we extend the example in Section 3 where the seller chooses no to invest ($i = 0$) or to invest ($i = 1$), the cost of which is $a > 0$. The buyer's value of trade is $v_i(q, \theta)$ when investment is $i = 0, 1$, and the seller's production cost is $c(q)$. Note there are two changes from the example in Section 3: we include a random variable θ and the level of trade q. While in Section 3 we assumed that q is either 0 or 1, in this subsection we consider the case of more general quantity to analyze effects of uncertainty. In particular, we assume that the optimal level of trade differs across realizations of the random variable, as described in the next paragraph. The true state (the realization of the random variable θ), which realizes after investment, is symmetrically observable but unverifiable. The quantity of trade and transfer payments are, however, verifiable.

For simplicity, we assume $q \in \{0, 1, 2\}$ and $\theta \in \{\theta_1, \theta_2\}$, and write $v_i^{qh} = v_i(q, \theta_h)$, $c_q = c(q)$, with $v_i^{0h} = c_0 = 0$. We also use the following notations: $\phi_i^{qh} = v_i^{qh} - c_q$ and $\Delta_v^{qh} = v_1^{qh} - v_0^{qh}$. The value of investment for alternative use is $m_i \geq 0$ when investment is i, and we allow $\Delta_m = m_1 - m_0$ to be positive or negative.

We make the following assumptions: (a) value v_i^{qh} and cost c_q are strictly increasing in q for all i and h; (b) $\phi_i^{11} > \phi_i^{21} \geq m_i$ and $\phi_i^{22} > \phi_i^{12} \geq m_i$ for all i; (c) $\Delta_v^{1h} \geq 0$, $\Delta_v^{2h} > 0$, and $\Delta_v^{2h} \geq \Delta_v^{1h}$ for all h. Assumption (b) implies that the optimal quantity in state h is $q = h$. Assumption (c) implies that the gain from trade is increasing in investment for each state, and exhibits increasing differences in (i, q); investment and quantity are complementary.

We assume for simplicity that each state is equally likely to arise, and

$$\frac{1}{2}\Delta_v^{11} + \frac{1}{2}\Delta_v^{22} > a \tag{16}$$

which implies that the efficient (first-best) solution is to make an investment (and trade $q = h$ when the true state is $h = 1, 2$).

Spot transaction When no formal contract is written under spot transaction, the parties renegotiate and agree with the efficient quantity of trade after uncertainty is resolved. We assume that the renegotiation transfer from the seller to the buyer is determined by the generalized Nash bargaining solution with the seller's share being $\alpha \in [0, 1)$. When investment is i, the renegotiation transfer in state h is determined such that the seller's ex post payoff is

$$\alpha\phi_i^{hh} + (1-\alpha)m_i.$$

The seller's ex ante expected payoff is thus

$$\frac{1}{2}\alpha\phi_i^{11} + \frac{1}{2}\alpha\phi_i^{22} + (1-\alpha)m_i - ai.$$

It is optimal for the seller not to invest ($i = 0$) if

$$\frac{1}{2}\alpha\phi_1^{11} + \frac{1}{2}\alpha\phi_1^{22} + (1-\alpha)m_1 - a < \frac{1}{2}\alpha\phi_0^{11} + \frac{1}{2}\alpha\phi_0^{22} + (1-\alpha)m_0$$

which is equivalent to

$$\frac{1}{2}\alpha\Delta_v^{11} + \frac{1}{2}\alpha\Delta_v^{22} + (1-\alpha)\Delta_m < a. \tag{17}$$

We assume this condition to hold so that the holdup problem (underinvestment) arises. A necessary condition is

$$a > \Delta_m, \tag{18}$$

that is, the seller has no incentive to invest under alternative opportunities.

Next, suppose that the buyer and the seller write a formal contract $(\overline{q}, \overline{p})$ where $\overline{q} \in \{1, 2\}$ is the quantity traded and $\overline{p}$ is the payment from the buyer to the seller.

First suppose $\overline{q} = 1$. If the true state is θ_1, the contract implements the efficient level of trade and hence there is no room for renegotiation. If the true state is θ_2, the parties void the contract, renegotiate and agree to trade $q = 2$. The seller's ex post payoff is

$$\overline{p} - c_1 + \alpha \left\{ \phi_i^{22} - \phi_i^{12} \right\}.$$

The seller's ex ante expected payoff is thus

$$\overline{p} - c_1 + \frac{1}{2}\alpha \left\{ \phi_i^{22} - \phi_i^{12} \right\} - ai.$$

It is optimal for the seller to invest $(i = 1)$ if

$$\overline{p} - c_1 + \frac{1}{2}\alpha \left\{ \phi_1^{22} - \phi_1^{12} \right\} - a \geq \overline{p} - c_1 + \frac{1}{2}\alpha \left\{ \phi_0^{22} - \phi_0^{12} \right\}$$

which is equivalent to

$$\frac{1}{2}\alpha(\Delta_v^{22} - \Delta_v^{12}) \geq a. \tag{19}$$

In state θ_2, the seller obtains share α of the gain from renegotiation, $\phi_i^{22} - \phi_i^{12}$, which is weakly increasing in investment due to the assumption of complementarity. That is, $(\phi_1^{22} - \phi_1^{12}) - (\phi_0^{22} - \phi_0^{12}) \equiv \Delta_v^{22} - \Delta_v^{12} \geq 0$. Then, the seller chooses to invest if its ex ante expected return from investment, $\frac{1}{2}\alpha(\Delta_v^{22} - \Delta_v^{12})$, is greater than the investment cost a. This is condition (19).

Similarly, if the parties write a contract with $\overline{q} = 2$, the seller chooses to invest if

$$\frac{1}{2}\alpha(\Delta_v^{11} - \Delta_v^{21}) \geq a.$$

This condition never holds because $\Delta_v^{21} \geq \Delta_v^{11}$ by complementarity between investment and quantity. The price contract with $\overline{q} = 2$ thus cannot induce the seller to invest. We thus focus on contracts with $\overline{q} = 1$.

Writing a formal contract can be valuable even under spot transaction if both (17) and (19) hold. And the alternative-use value being decreasing in investment is a necessary condition for a formal contract to be of value. To see this, note that if $\Delta_m \geq 0$, the left-hand side of (17) is at least as large as $\alpha\Delta_v^{22}/2$, while the left-hand side of (19) is equal to or smaller than $\alpha\Delta_v^{22}/2$.

Repeated transactions We now show that a formal contract can be valuable within a broader range of parameter values under repeated transactions. Let us assume that (17) holds while (19) does not, so that the seller cannot be induced to invest under spot transaction. A formal contract along with repeated transactions can still help in this situation. We can show this most simply by considering a special case of $\alpha = 0$: the buyer can obtain all the surplus from renegotiation. In this case, (17) holds if $\Delta_m < a$, and (19) does not in fact hold. Under repeated transactions, it is not difficult to show that investment $i = 1$ can be implemented without a formal contract if and only if

$$a - \Delta_m \leq \frac{\delta}{1-\delta}\left(\frac{1}{2}\Delta_v^{11} + \frac{1}{2}\Delta_v^{22} - a\right). \tag{20}$$

(See Appendix for derivation.) Similarly, it can be shown that $i = 1$ is implemented with a formal contract if and only if

$$a \leq \frac{\delta}{1-\delta}\left(\frac{1}{2}\Delta_v^{11} + \frac{1}{2}\Delta_v^{22} - a\right). \tag{21}$$

(See Appendix for derivation.) The comparison is thus analogous to that between (1) and (4) in Section 3. This implies that, if $\Delta_m < 0$, there is a range of parameter values within which the buyer is strictly better off by offering a formal contract under repeated transactions, even though formal contracts cannot induce the seller to invest under spot transaction.

6.2 Vertical Integration

Vertical integration has been considered as an important remedy to the holdup problem in the literature. In our model, we have treated the seller and the buyer as separate firms without explicitly considering an option for them to merge vertically. In this subsection, we consider an extension of our model that incorporates the possibility of vertical integration between the seller and the buyer, by making use of the framework developed by Baker et al. (2002). Through analyzing the extension, we demonstrate that even if vertical integration is allowed, an optimal vertical structure can be non-integration in which the seller sells the product to the buyer under a formal price contract and repeated transactions.

In this extension, we consider an economic environment consisting of a seller, a buyer, and an asset. The seller needs to use the asset to produce the product. We consider two cases. (i) The seller owns the asset. In this case the seller and the buyer are not integrated, and we call this case "outsourcing." (ii) The buyer owns the asset. In this case the seller and the buyer are integrated and the seller is just an employee of the buyer. We call this case "employment." These terminologies follow

Baker et al. (2002). The owner of the asset has the residual right of control over the asset. Under outsourcing, the seller can thus use the asset freely, whether or not he actually trades with the buyer. Under employment, however, the buyer can exclude the seller from the use of the asset.

Our base model focuses on the case of outsourcing, where the seller can realize the alternative-use value m_i by using the asset to produce the product in an outside market. Under employment, the seller cannot use the asset when he does not trade with the buyer, and hence we assume that the disagreement payoff to the seller as well as to the buyer is zero. This implies that formal price contracts cannot help resolve the holdup problem under employment, and hence in our analysis we assume that no formal contract is written under employment. Following the standard literature of the property rights approach (Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995), we assume that ownership only affects the payoffs at the threat point, while bargaining power is invariant.[16]

To simplify the analysis, we use our three-investment example in Subsection 5.4 with some modification. We assume, as before, $\Delta_v = v_2 - v_1 = v_1 - v_0$. We alter, however, the assumptions on the investment costs and the alternative-use values as follows: $\Delta_a = a_2 - a_1 > a_1 - a_0 = a_1 > 0$ ("convexity" of the cost function) and $\Delta_m = m_2 - m_1 = m_1 - m_0$. We allow Δ_m to be either positive or negative, but we assume $\Delta_v > \Delta_m$. We also assume $\Delta_v > \Delta_a$ so that $a^* = a_2$.

First consider spot transaction. Recall that since the investment is purely co-

[16]Baker et al. (2002) assume that under employment, the buyer has all the bargaining power and can take the product without paying anything to the seller. In other words, under integration the seller cannot reap any return from his/her investment in human capital, and it is hard to justify this assumption as long as investment affects his/her human capital. If we instead adopt their assumption, then relational outsourcing with a formal price contract turns out to be equivalent to relational employment, in a sense that Condition (DE-FP) is equivalent between these two cases. A related remark is found in a footnote of their paper (footnote 6, p.44) where they argue, thanking a referee for pointing it out, that employment "corresponds to a specific-performance contract that requires the upstream party to deliver the good to the downstream party." However, analogy to the contract here seems misleading because the downstream party is not required to pay any money in this setting, which is unrealistic if this is interpreted as a specific-performance contract.

operative, formal price contracts perform at most as well as no contract under spot transaction. We assume $2(\alpha\Delta_v + (1-\alpha)\Delta_m) < a_2$, which implies that under our "spot outsourcing" without a formal contract, the seller prefers both a_0 and a_1 to a_2, and hence the holdup problem arises. The optimal investment for the seller, a^o, is given as follows:

$$a^o = \begin{cases} a_1 & \text{if } \alpha\Delta_v + (1-\alpha)\Delta_m \geq a_1 \\ a_0 & \text{if } \alpha\Delta_v + (1-\alpha)\Delta_m < a_1 \end{cases}$$

Under "spot employment," the renegotiated price after investment a_i is $r_i = \alpha v_i$. We assume that there is underinvestment in spot employment as well. The following condition is sufficient.

$$2\alpha\Delta_v < a_2$$

The optimal investment for the seller, denoted by a^e, is given as follows:

$$a^e = \begin{cases} a_1 & \text{if } \alpha\Delta_v \geq a_1 \\ a_0 & \text{if } \alpha\Delta_v < a_1 \end{cases}$$

If $a^e = a_i$, define the seller's payoff, the buyer's payoff, and the joint value, respectively, as follows:

$$\pi_S^e = w + r_i - a_i, \quad \pi_B^e = v_i - w - r_i, \quad \pi^e = v_i - a_i$$

The comparison of spot employment with spot outsourcing is simple. If the "market incentive" is positive ($\Delta_m > 0$), $a^o \geq a^e$, while $a^o \leq a^e$ if the market incentive is negative. Spot employment eliminates the effect of the alternative-use value on the renegotiated price. It is optimal if and only if the market incentive attenuates the seller's incentive to invest.

Next we analyze repeated transactions. Employment under repeated transactions is called "relational employment," while outsourcing under repeated transactions is called "relational outsourcing." The major issue here is whether ownership can be renegotiated after either party reneges on the relational contract. Baker et al. (2002) assume that renegotiation costs are low enough to allow the parties to negotiate over asset ownership. Under their assumption, the seller and the buyer thus choose the optimal spot ownership structure, either spot outsourcing (if $\Delta_m > 0$) or spot employment (if $\Delta_m < 0$) after reneging, and maintain that form forever. Halonen (2002) introduces renegotiation costs explicitly, and considers the other polar case in which costs are so high that the ownership structure will not be renegotiated.

If renegotiation over asset ownership is feasible, it turns out that the comparison between relational outsourcing with no formal contract and relational employment is the same as that between spot outsourcing and spot employment. That is, relational employment is optimal if and only if $\Delta_m < 0$. And noting that $\Delta_m < 0$ is a necessary condition for a formal price contract to dominate the no contract case in our model, we can conclude that writing a formal price contract under relational outsourcing is never optimal because relational employment can provide stronger investment incentives for the seller through renegotiation.

In the rest of this subsection, we hence focus on the second case in which renegotiation over asset ownership is infeasible. Condition (DE-NC) for relational outsourcing with no formal contract is rewritten as follows:

$$a_2 - 2(\alpha\Delta_v + (1-\alpha)\Delta_m) \leq \frac{\delta}{1-\delta}(\pi_2 - \pi_0) \qquad \text{if } \alpha\Delta_v + (1-\alpha)\Delta_m < a_1 \quad (22)$$

$$\Delta_a - (\alpha\Delta_v + (1-\alpha)\Delta_m) \leq \frac{\delta}{1-\delta}(\pi_2 - \pi_1) \qquad \text{if } \alpha\Delta_v + (1-\alpha)\Delta_m \geq a_1 \quad (23)$$

The corresponding condition for relational outsourcing with a formal price contract is given as follows:

$$a_2 \leq \frac{\delta}{1-\delta}(\pi_2 - \pi_0) \qquad \text{if } \alpha\Delta_v + (1-\alpha)\Delta_m < a_1 \tag{24}$$

$$a_2 \leq \frac{\delta}{1-\delta}(\pi_2 - \pi_1) \qquad \text{if } \alpha\Delta_v + (1-\alpha)\Delta_m \geq a_1 \tag{25}$$

Finally, the necessary and sufficient condition for a_2 to be implemented under relational employment can be derived similarly and is given as follows:

$$a_2 - 2\alpha\Delta_v \leq \frac{\delta}{1-\delta}(\pi_2 - \pi_0) \qquad \text{if } \alpha\Delta_v < a_1 \tag{26}$$

$$\Delta_a - \alpha\Delta_v \leq \frac{\delta}{1-\delta}(\pi_2 - \pi_1) \qquad \text{if } \alpha\Delta_v \geq a_1 \tag{27}$$

Now suppose $\Delta_m < 0$. If $\alpha\Delta_v \geq a_1 - (1-\alpha)\Delta_m$ so that $a^o = a^e = a_1$, or if $\alpha\Delta_v < a_1$ so that $a^o = a^e = a_0$, then the future loss from reneging is the same under relational outsourcing with no formal contract, relational outsourcing with a fixed-price contract, or relational employment. And hence relational employment (integration) is optimal. However, if $a_1 \leq \alpha\Delta_v < a_1 - (1-\alpha)\Delta_m$ so that $a^o = a_0 < a_1 = a^e$, comparison is involved. In this case, we have to compare among (22), (24), and (27). Under relational outsourcing with or without a formal contract, the future per period loss is $\pi_2 - \pi_0$, which is larger than $\pi_2 - \pi_1$, the future per period loss under relational employment. However, the left-hand side of (22) and that of (24) are also larger than that of (27). We can thus show that depending on parameter values, either form can be optimal. The following example in particular demonstrates that relational outsourcing with a formal price contract can be optimal, even though integration is allowed.

Example Suppose $\alpha = 1/2$ and $\Delta_v + \Delta_m < 0$. The triangle surrounded by bold lines in Figure 1 represents the area where the efficient investment is a_2 ($\Delta_a < \Delta_v$), there is underinvestment in spot employment ($\Delta_v < a_2$), and $a^o = a_0 < a_1 = a^e$

holds ($2a_1 < \Delta_v < 2a_1 - \Delta_m$) so that the relevant dynamic enforcement conditions are (22), (24), and (27). Since we assume $\Delta_v + \Delta_m < 0$, the left-hand side of (22) is larger than that of (24), and hence relational outsourcing with a formal contract can implement the efficient investment for smaller discount factors than relational outsourcing with no formal contract. The remaining comparison is hence between relational outsourcing with a formal contract and relational employment. From (24) and (27) we find that if $3a_2 - 4a_1 < 2\Delta_v$ holds, there is a range of discount factors in which the efficient investment is implemented under relational outsourcing with a formal contract but not under relational employment. This condition is satisfied in the shaded area in Figure 1.

7 Concluding Remarks

This paper has offered a new perspective on the role of formal contracts in resolving the holdup problem. In situations where formal contracts have no value under spot transaction due to the cooperative nature of the relation-specific investment, we have shown that writing a simple fixed-price contract can be valuable under repeated transactions. In our model, there is a range of parameter values in which a formal price contract combined with a relational contract can help mitigate the holdup problem, while under another parameter range not writing a formal contract but entirely relying on a relational contract increases the total surplus of the buyer and the seller. The key factor in distinguishing between these two cases is how the investment affects the alternative-use value.

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Appendix

Here we explain how to derive conditions (20) and (21).

First consider the case of no formal contract. In this extension, we can focus on the class of relational contracts in which the parties agree that they trade q and the buyer pays b_i^q to the seller if the true state is $h = q$. It is then optimal for the seller to choose $i = 1$ if

$$\frac{1}{2}(b_1^1 - b_0^1) + \frac{1}{2}(b_1^2 - b_0^2) \geq a \tag{IC$'$}$$

holds. If the buyer does not pay b_i^q, then the parties renegotiate and the buyer offers m_i, and hence the buyer's reneging temptation is $\max_{q,i}(b_i^q - m_i)$. Similarly, the seller's reneging temptation is $-\min_{q,i}(b_i^q - m_i)$.

The sum of the reneging temptations is

$$\max_{q,i}(b_i^q - m_i) - \min_{q,i}(b_i^q - m_i)$$

that must be no greater than the sum of the future loss, which is equal to the right-hand side of (20) and (21). By definition and (IC$'$)

$$\begin{aligned}
&\max_{q,i}(b_i^q - m_i) - \min_{q,i}(b_i^q - m_i) \\
&\quad \geq \left(\frac{1}{2}b_1^1 + \frac{1}{2}b_1^2 - m_1\right) - \left(\frac{1}{2}b_0^1 + \frac{1}{2}b_0^2 - m_0\right) \\
&\quad \geq a - \Delta_m
\end{aligned}$$

Condition (20) is hence necessary. For sufficiency, suppose (20) holds. We define (b_i^q) so as to satisfy the following conditions:

$$b_0^1 = b_0^2$$

$$b_1^1 - b_0^1 = b_1^2 - b_0^2 = a$$

It is then easy to show that (IC$'$) holds. Furthermore, given $\Delta_m < a$ we have

$$\max_{q,i}(b_i^q - m_i) = b_1^1 - m_1 = b_1^2 - m_1$$
$$\min_{q,i}(b_i^q - m_i) = b_0^1 - m_0 = b_0^2 - m_0$$

and hence

$$\max_{q,i}(b_i^q - m_i) - \min_{q,i}(b_i^q - m_i) = a - \Delta_m$$

which is, by (20), no greater than the future loss. Condition (20) is hence sufficient.

Next consider the case of a formal price contract $(\overline{q}, \overline{p})$. The parties agree, in addition to the formal contract, that they trade q and the buyer pays b_i^q to the seller if the true state is $h = q$. The seller's incentive compatibility condition is the same as before:

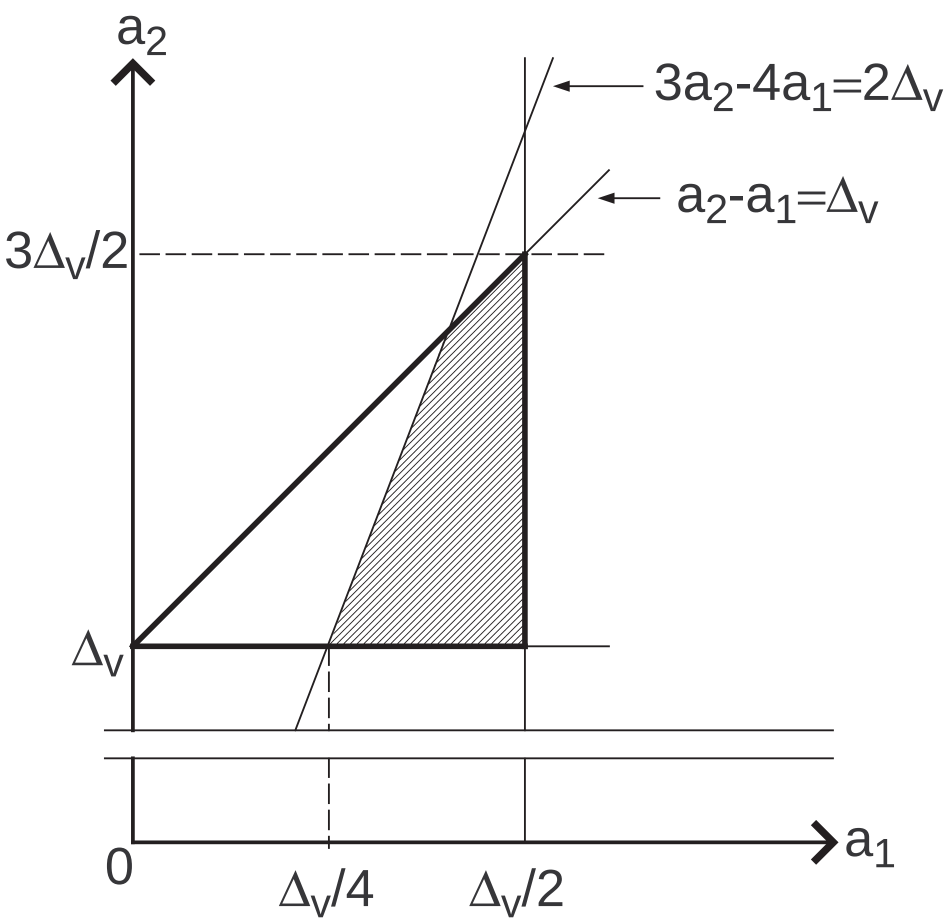
$$\frac{1}{2}(b_1^1 - b_0^1) + \frac{1}{2}(b_1^2 - b_0^2) \geq a \tag{IC$'$}$$

Suppose $\bar{q} = 1$, and the buyer does not pay b_i^q in state q. If the true state is $q = \overline{q} = 1$, the formal price contract is efficient and there is no room for renegotiation. The buyer's payoff from reneging is thus $b_i^q - \overline{p}$. If the true state is $q = 2 \neq \overline{q}$, then the parties renegotiate to trade q and the buyer offers $\overline{p} - c_1 + c_2$. The buyer's reneging temptation is therefore $\max_i\{b_i^1 - \overline{p}, b_i^2 - (\overline{p} - c_1 + c_2)\}$. Similarly, the seller's reneging temptation is $-\min_i\{b_i^1 - \overline{p}, b_i^2 - (\overline{p} - c_1 + c_2)\}$. Summing them up and using (IC$'$) yields,

$$\begin{aligned}
&\max_i\{b_i^1 - \overline{p}, b_i^2 - (\overline{p} - c_1 + c_2)\} - \min_i\{b_i^1 - \overline{p}, b_i^2 - (\overline{p} - c_1 + c_2)\} \\
&\geq \left(\frac{1}{2}b_1^1 + \frac{1}{2}b_1^2 - \overline{p} - \frac{1}{2}(c_2 - c_1)\right) - \left(\frac{1}{2}b_0^1 + \frac{1}{2}b_0^2 - \overline{p} - \frac{1}{2}(c_2 - c_1)\right) \\
&\geq a,
\end{aligned}$$

that must be no greater than the future loss. Similarly, we obtain the same condition when $\bar{q} = 2$. Then, through the analogous procedure as in the no formal contract case presented above, we find that (21) is the necessary and sufficient condition.

Figure 1: Optimality of Writing a Formal Contract Without Integration



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