INCOMPLETE CONTRACT AND OVERINVESTMENT

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Abstract

We show that the underinvestment result in the incomplete contract literature relies on the assumption that either the investment is selfish, or the bargaining after the investment has been made is under symmetric information, or both. Contract incompleteness might lead to overinvestment when the investment is unobservable and cooperative (the buyer's value of the good depends on the seller's investment), and the players have asymmetric information during the bargaining (the buyer has private information regarding his value for the good). We also show that when the investment is observable but not verifiable, using an option contract might be able to restore efficient investment and amount of trade.

Keywords: incomplete contract, cooperative investment, asymmetric information bargaining

JEL Classification: L14

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1 Introduction

The classical holdup problem in a buyer-seller relationship consists of two stages. First is the investing stage: before the state of the world is known, the buyer or the seller invests in specific capital, which has more value if they trade with each other than with outsiders. Then comes the bargaining stage: after the state of the world is known, they bargain over the terms of trade. In the bargaining stage, since the investments have been sunk, the investing party is vulnerable to the other's opportunistic behavior. The risk then leads to underinvestment. Contracting does not help since neither the investments nor the state of the world are verifiable. This underinvestment problem is the main concern of Williamson (1975, 1985), Grout (1984), Tirole (1986), Grossman and Hart (1986), and Hart and Moore (1988).

In this article, we argue that when the information is asymmetric in the bargaining stage, and the investment is cooperative,[1] the lack of contract can have the opposite result; namely, the parties might *overinvest*. To illustrate, suppose that the buyer is to buy one unit of a good from the seller, and only the seller invests to improve the quality of the good. If the seller invests $I = 0$, the good is not improved and is worth 3 to the buyer. If $I = 2$, with probability 1/2 the good is worth 10 to the buyer, and with probability 1/2 the worth is still 3. If $I = 4$ the good's worth is 10 with probability 3/4 and 3 with probability 1/4. Assume that no other levels of investment are possible, and the production cost is 0. The net expected joint surpluses of the three investment levels are then 3, 4.5, and 4.25, and therefore the efficient investment is $I^* = 2$.

Suppose that the seller makes a single take-it-or-leave-it offer to the buyer in the bargaining, and only the buyer knows the worth of the good. If the buyer rejects it, the good loses its value and each gets 0 from the bargaining. The seller will charge 3 if $I = 0$, and 10 if $I = 2$ or 4; for if $I \geq 2$, the seller's expected revenue is at least 5 if charging 10,

[1] Che and Hausch (1999) define cooperative investments as those that benefit the trading partner of the investing party, and selfish investments as those that benefit only the investing party.

and 3 if charging 3. Hence the net expected values to the seller of the three investment levels are 3, 3, and 3.5. The seller will invest $I = 4$, more than the efficient level.

Most papers discussing the holdup problem make two assumptions. First, the investment is selfish. Second, except for Tirole (1986), the literature assumes that in the bargaining stage, the two parties have complete information. The above overinvestment example violates both assumptions. Note also that the bargaining is inefficient since the parties might not realize the surplus of the trade. However, it is this inefficiency that makes the seller overinvest.

Che and Hausch (1999) show that cooperative investments not only are common in practice, they might also nullify contracting as a remedy to the underinvestment problem. Yet, Che and Hausch (1999) keep the assumption that the bargaining is under symmetric information, and their model does not include the possibility of overinvestment. When the two parties bargain under complete information, Rubinstein (1982) shows that the Nash bargaining solution can be supported by a sequential, noncooperative bargaining. However, the bargaining game will reach its equilibrium immediately; there will be no haggling. When the Nash bargaining solution is the canonical rule to divide the surplus from trade, then unless the investing party enjoys complete bargaining power ex post, it has to share part of the investment benefit with the other party, and hence underinvests. This result is almost synonymous with the incomplete contract literature.

One factor that makes a contract incomplete is that public measures of the benefits of the specific investments are not available, and hence the benefits are unverifiable to the court. By the same token, the benefits might be unobservable to the trading partner as well. For example, the buyer knows better than the seller whether the machine the seller designs fits his current plan; an employer knows better than his employee the market value of the employee's invention.

In contrast to Rubinstein (1982), Fudenberg et al. (1985) summarize the two key aspects of bargaining: "Bargaining involves a succession of steps, and the bargainers do not know the value to others of reaching an agreement." However, if the investment is selfish, Tirole (1986) shows that the information structure in the bargaining stage does not affect the holdup problem.[2] When the parties have asymmetric information, the share of each depends on the rule of the bargaining. But since the probability of reaching the efficient volume of trade is lower than that under complete information,[3] the investing party's share of the benefit generated by its investment will not be 100 percent, and the underinvestment result persists.

The bargaining rule in our simple example is special. In sequential bargaining games under incomplete information, the equilibrium outcomes are very sensitive to the choice of the extensive form, and the game in which the party with private information can make offers can have many perfect Bayesian equilibria (PBE).[4] Therefore we restrict our attention to the case that ex post only the buyer has private information and the seller makes a take-it-or-leave-it offer in the bargaining. This game form can have unique PBE, and allows us to concentrate on the ex ante investment problem.

Since the seller sets a monopoly price in the bargaining game, they might not trade even though it is common knowledge that the good's value exceeds the seller's cost. If the investment is selfish, then the inefficient amount (probability) of trade can only reduce the seller's incentive to invest. However, if the investment is cooperative, the seller might invest more than the efficient level.

When the investment is cooperative, if the seller invests more, the buyer is more likely to get high value for the good. This then will enable the seller to be tougher in the bargaining. The intuition is similar to the quality choice of a durable-good monopolist. Chi (1999) shows that the monopolist will choose a quality of his product that is higher than the efficient level to attract the high-demand consumers to accept his high prices rather than waiting for lower prices.

There have been a few overinvestment results in the literature. If there is complete information in the bargaining stage, the payoff to either party depends on its bargaining power and the status quo. Since authority changes the status-quo point in the bargaining process, Grossman and Hart (1986) show that if authority is not properly assigned, the

[2]If the investment is verifiable but the transfer price is not contractable, Tirole (1986) shows that it is possible to have an overinvestment equilibrium. We will discuss more about the result later.

[3]See Myerson and Satterthwaite (1983).

[4]See the review in Fudenberg and Tirole (1991).

investment would not be efficient. Consider the example given by Tirole (1988, p.31). The seller and the buyer will trade for sure, and the issue is whether they should invest to increase the surplus of the trade. The seller can improve the quality of the good by incurring a fixed amount of cost c. Whether the improvement creates a value $V > c$ depends on the buyer's investment in "flexibility." If the buyer spends $x^2/2$, the probability that $V > c$ will be x. If the buyer has authority, the status quo is that the improvement would always be made. Since the buyer does not need to share the cost c, the buyer overinvests to have a higher-than-optimum probability that $V = v$.

Aghion et al. (1994) show that the underinvestment result strongly depends on how the status quo is defined and on the allocation of bargaining power. There exists an optimal design of the status quo and the bargaining power that can achieve the efficient levels of trade and investment. Although overinvestment is possible when the contract is not properly designed, this cannot happen in the equilibrium. Edlin and Hermalin (2000) find that investment can also affect the status quo in the bargaining process. Suppose that when the seller does not trade with the buyer, he can consume the good or sell the good to a third party, which creates a lower value than trading with the buyer. If the seller's investment increases the value to himself or the third party, then higher level of investment strengthens the seller's bargaining position. This threat-point effect boosts the seller's incentive to invest. If the threat-point effect outweighs the holdup effect, the seller will overinvest.

In our model there is asymmetric information during the bargaining and the good has no value to the seller or any third party, and therefore our overinvestment result is unrelated to the status quo. Tirole (1986) also discusses bargaining under asymmetric information. He shows that if the seller and the buyer can have contract on selfish investment but cannot have contract on price, then they might write a contract specifying an investment level higher than the efficient level. However, if the investment is not contractable, that is, the investment is either unobservable or observable but not verifiable, then the investment is less than efficiency. In our model, we have an overinvestment equilibrium when the investment is not contractable, and when the investment is contractable but the price uncontractable, the investment level is equal to the efficient level.

When contract incompleteness means that the the investment is observable but not verifiable, Maskin and Tirole (1999) criticize the incomplete contract approach for not considering mechanisms the two parties can use to improve the results of contract incompleteness. Indeed, several authors have shown that simple contracts can solve the holdup problem. Chung (1991), Aghion et al. (1994), and Nöldeke and Schmidt (1995) prove that investment can be efficient if the initial contract can (i) specify a default option in case the bargaining breaks down, and (ii) assign all bargaining power to one party. Rogerson (1992), Demski and Sappington (1991), and Bernheim and Whinston (1998) also propose a simple option contract that implements the efficient investment, assuming that the option contract cannot be renegotiated. Edlin and Hermalin (2000) allow renegotiation of the option contract and get a condition under which the two sides reach the efficient outcome. However, Che and Hausch (1999) show that these simple contracts can restore efficiency because the investment is selfish; when the investments are cooperative, contracts do not help.

A common assumption of these papers that propose contractual remedies is that the bargaining after the option expires is under complete information, and always leads to ex post efficiency. In our framework, the bargaining is under incomplete information and cannot have ex post efficiency. We find that an option contract can implement the efficient investment if that investment makes the buyer get zero surplus from forgoing the option and bargaining with the seller.

The paper is organized as follows. Section 2 presents the overinvestment result in a basic two-type model, as well as a continuous-type model, and compares the results with Tirole's (1986). Section 3 considers the case in which the seller's investment is not only observable, but the two parties are able to design contracts based on the investment. Section 4 concludes.

2 The Overinvestment Result

2.1 The Framework

Assume that a buyer is going to buy one unit of an indivisible good from a seller. There are two stages. In stage 1, the seller invests to improve the value of the good to the buyer. The cost of the investment is $I(x) = cx^2/2$, which will improve with probability x the value of the good to the buyer; with probability $1 - x$ the investment fails to improve the value. When there is no investment or investment fails, the value to the buyer is $V = 1$. When the investment works, the value is $V = \beta$, $\beta > 1$. Assume that the seller incurs no cost in producing the good, and receives no utility from keeping the good, so it is efficient to trade no matter what.

In this section, we assume that the investment is unobservable.[5] In section 3, we will consider the case in which the investment is observable but not verifiable.

Stage 2, the bargaining stage, starts after the buyer learns the good's value. During this stage, the buyer has private information about the good's value. The seller offers the buyer a take-it-or-leave-it price p. If the buyer accepts, the game ends and the buyer's payoff is $V - p$, where $V = 1$ or β, and the seller's $p - I(x)$. If the buyer rejects, then the game ends with no trade. Each side has reservation utility 0. The time line of the game is shown in figure 1.

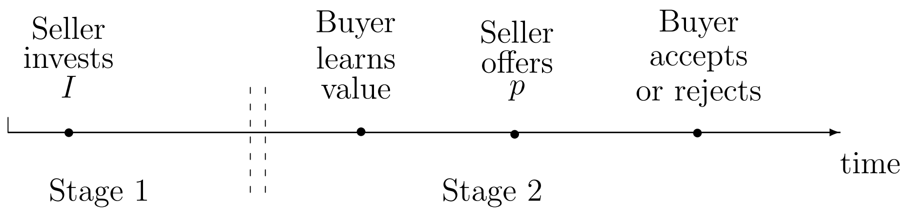

Figure 1: Time line

[5]If the investment is observable but not verifiable, then we need to assume that the buyer learns the good's value immediately after the seller invests, so that the two parties cannot have any contract that specifies their moves between the time the seller invests and the time the buyer learns the value.

2.2 The Efficient Level of Investment

Since $V \geq 1$, and the seller has no production cost, trading is optimal. The efficient level of investment is either 0, which entails a welfare of 1, or the solution to

$$\max_x \; x\beta + (1-x) - \frac{cx^2}{2}.$$

Let x^* be the solution, then

$$x^* = \frac{(\beta - 1)}{c}, \tag{1}$$

and the welfare is $\mathcal{W}(x^*) = 1 + (\beta - 1)^2/(2c)$. Since $\mathcal{W}(x^*) > 1$, it is efficient to invest.

2.3 Bargaining and Investment

How much the seller invests depends on the expected revenue he can get from the bargaining stage. Since only the buyer knows the value, we say that the buyer's type is high if $V = \beta$, and low if $V = 1$.

The seller makes a single take-it-or-leave-it offer p to the buyer. The buyer accepts the offer if and only if $p \leq V$. The seller's optimal (profit-maximizing) price is then

$$p(x) = \beta \text{ if } \; x \geq 1/\beta; \; p(x) = 1 \text{ otherwise.} \tag{2}$$

If the seller is going to charge $p = 1$, he will not invest in stage 1, and his profit is 1. Suppose he invests; then his investment solves:

$$\max_{x \geq 1/\beta} \;\; x\beta - \frac{cx^2}{2}.$$

The solution is $\hat{x} = \beta/c$, larger than $1/\beta$ if $c < \beta^2$; the profit is $\hat{\Pi}_1 = \beta^2/(2c)$, more than 1 if $c < \beta^2/2$.

From now on, we assume that it is profitable for the seller to invest, and that both x^* and $\hat{x}$ are strictly less than 1 (that is, we exclude corner solutions):

Assumption 1. $\beta < c < \beta^2/2$.

Comparing the seller's investment with the efficient level, we have

Proposition 1. Under assumption 1, the seller overinvests: $\hat{x} > x^*$.

2.4 Continuous Distribution of the Values of the Good

Overinvestment can occur when the good's value is drawn from a continuous distribution. Suppose that the support of V is on $[\underline{V}, \bar{V}]$, $\underline{V} > 0$. The conditional cumulative distribution of V is $F(v|x) \equiv \Pr[V \leq v|x]$, where x is the seller's investment on the improvement. The density of $F(\cdot)$ is $f(\cdot)$. The cost of the investment is $I(x) = cx^2/2$, and the cost of production is 0. Higher x improves the good's value in the sense of first-order stochastic dominance (FOSD): $F_x \equiv \partial F(v|x)/\partial x \leq 0$.

If the price is p, the buyer will accept if and only if $V \geq p$. Therefore we can treat $q(p,x) \equiv 1 - F(p|x)$ as the demand curve, where q is like the quantity demanded; and $p = P(q,x) = F^{-1}(1-q|x)$ the inverse demand curve.[6] The FOSD assumption then means that higher x increases the quantity sold, other things equal: $q_x(p,x) \geq 0$, or that higher x makes the seller tougher in bargaining: $P_x(q,x) = F_x^{-1}(1-q|x) \geq 0$.[7]

Since $\underline{V}$ is larger than the cost of production, it is always efficient for them to trade. The gross surplus from trade is

$$\int_{\underline{V}}^{\bar{V}} V dF(V|x) = \int_0^1 P(q,x)dq,$$

and the efficient level of investment x^* solves:

$$\max_x \int_0^1 P(q,x)dq - \frac{cx^2}{2}.$$

[6]Bulow and Roberts (1989) use the demand function interpretation to synthesize the optimal auction models.

[7]By FOSD, increasing x by dx while keeping p unchanged gives a higher probability of trade: $q(p, x + dx) \geq q(p,x)$. Or, the seller can increase price by δp and keep the same probability of trade: $q(p+\delta p, x + dx) = q(p,x)$.

The first order condition for x^* is

$$\int_0^1 P_x(q, x^*)dq = cx^* \tag{3}$$

If we plot q on the x-axis and p (or V) on the y-axis, and interpret the height of $P(q, x)$ as the willingness to pay, then the left hand side is the change in the average willingness to pay caused by the investment. Efficiency requires that the marginal cost of investment equals the marginal increase of average valuation.

As in the two-type case, we derive the seller's profit-maximizing investment in two steps. After incurring a cost $cx^2/2$, the seller sets its take-it-or-leave-it price to maximize the expected total revenue $R = P(q, x)q$. Since the cost of production is 0, the seller sets the marginal revenue to 0:

$$MR = \frac{\partial R}{\partial q} = P(q, x) + qP_q(q, x) = 0. \tag{4}$$

Assume that the second-order condition is satisfied, or MR is decreasing in q.

Let the revenue-maximizing solution be $\hat{q}(x)$, then the seller chooses x to maximize

$$\max_x \; P(\hat{q}(x), x)\hat{q}(x) - \frac{cx^2}{2}.$$

Using the Envelope theorem, the solution $\hat{x}$ satisfies

$$\hat{q}(\hat{x})P_x(\hat{q}(\hat{x}), \hat{x}) = c\hat{x}. \tag{5}$$

Comparing (3) with (5), we see that the same intuition provided by Spence (1975) holds: the seller equates the marginal cost of investment with the increase in the willingness to pay times the probability of trade, while the efficiency requires that the marginal cost of investment equals the marginal increase of average valuation. It is therefore possible that $\hat{x} > x^*$. Here is an example:

Assume that the good's value is uniformly distributed on $[1, 2]$. After the seller incurs the investment cost $cx^2/2$, a value $V \in [1,2]$ becomes $\tilde{V} = V + x(2-V)$. The density function becomes

$$f(V|x) = \begin{cases} 0 & \text{if } 1 \leq V < 1+x \\ 1/(1-x) & \text{if } 1+x \leq V \leq 2, \end{cases}$$

and the distribution function is $F(V|x) = (V-1-x)/(1-x)$; $F_x \leq 0$ as required. Transforming $F(\cdot)$ into the demand function, we have

$$P(q,x) = 2 - q(1-x),$$

where $0 \leq q \leq 1$. The efficiency condition (3) requires that

$$\int_0^1 P_x dq = cx^*,$$

which entails $x^* = 1/(2c)$. Revenue maximizing requires that $MR = 0$, but here we have a corner solution: $\hat{q}(x) = 1$ for all $x \geq 0$, and therefore $P(1,x) = 1+x$. The seller chooses x to maximize

$$1 + x - \frac{cx^2}{2},$$

and we have $\hat{x} = 1/c > x^*$: the seller overinvests.

2.5 Comparisons with Tirole (1986)

Uncontractable Investment

That the seller overinvests in cooperative investment is the total opposite of propositions 1 and 3 of Tirole (1986), which says that uncontractable selfish investment is less than the optimum under asymmetric information bargaining unless the bargaining is efficient; whereas in our two-type case, the seller's cooperative investment leads to inefficient bargaining, since the low-type buyer is cut off from purchasing. The seller cares only about the marginal revenue his investment can generate from the high-type buyer, while the efficiency requires that the marginal cost of investment equals the marginal increase of average valuation. Hence the seller is more aggressive in investment than the optimum. The bargaining is efficient if the seller charges $p = 1$, but then the seller does not invest. The difference between the efficiency and the seller's incentive to invest is similar to Spence (1975), who shows that a monopolist might offer an above-efficiency quality.

Contractable Investment

When the investment is contractable but the price not, the seller and the buyer will decide a level of investment to maximize their joint surpluses subject to the constraint that the price is in the equilibrium of the bargaining stage. Tirole (1986, proposition 2) shows that they will contract on an investment level that is higher than the level when the investment is unobservable. He also presents an example of overinvestment. Here we show that when the investment is cooperative and contractable, but the price not contractable, the mutually agreed-on investment level will be the efficient level, which is *less* than the level when the investment is unobservable.

Since the seller will set $p(x) = \beta$ when $x \geq 1/\beta$, and $p(x) = 1$ when $x < 1/\beta$, if the seller and the buyer can agree on an investment level, they would choose between

$$\mathcal{W}_1 = \max_{x \geq 1/\beta} \; x\beta - \frac{cx^2}{2} = \frac{\beta^2}{2c} \tag{6}$$

and

$$\mathcal{W}_2 = \max_{x \leq 1/\beta} \; x\beta + (1-x) - \frac{cx^2}{2}. \tag{7}$$

Denote by $\tilde{x}$ the level of investment set by the seller and the buyer's contract.

Proposition 2. Under assumption 1, $\tilde{x} = x^* < \hat{x}$, where $\hat{x}$ is the level of investment when the investment is unobservable.

Proof. Since assumption 1 implies that $\beta > 2$ and hence $\beta(\beta-1) > \beta^2/2$, $x^* = (\beta-1)/c < 1/\beta$ and $p(x^*) = 1$. Therefore the seller and the buyer can implement the efficient level of investment by setting $\tilde{x} = x^*$, and get $\mathcal{W}_2 = \mathcal{W}(x^*)$, the maximal joint surpluses. Since $\hat{x} > x^*$, the mutually agreed-on investment level is less than that when investment is unobservable. □

The assumption that investment is contractable is quite strong. In section 3, we show that there exists an option contract that can implement x^* if the investment is observable but not contractable.

3 Option Contract

Assume now that the investment is observable but not verifiable to the buyer, and the time between the seller's investing and the buyer's learning the value of the good is long enough for them to implement an option contract. The seller can offer an option contact at the beginning of the first stage that gives the buyer the right to purchase the good at price p^o before the end of the first stage; that is, the buyer can purchase the good after the buyer observes the seller's investment but before he learns the good's value. If we think of the investment as the process to improve the qood's quality, the end of the first stage could be determined by the completion of the process. The buyer then needs to decide whether to exercise the option before the process is completed.

If the buyer exercises the option, the good is transferred at price p^o and the game ends. If the buyer lets the option expire, then they bargain in the second stage as before; namely, the seller offers a take-it-or-leave-it price and the buyer accepts or rejects. Whether the buyer exercises his option then depends on p^o and his expected payoff from the bargaining. Likewise, whether the seller offers the option contract depends on his expected profit from bargaining. We summarize the sequence of moves in figure 2.

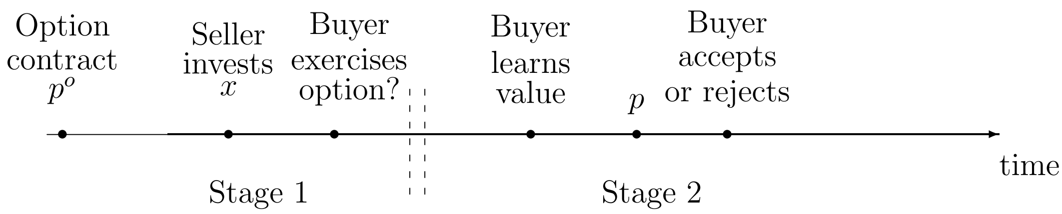

Figure 2: Option contract time line

We solve the game by backward induction. Given that the seller offers an option and spends the cost $cx^2/2$, the buyer knows the seller's pricing strategy in the bargaining stage if the buyer lets the option expire, and therefore he exercises the option if and only if the option gives a higher expected utility. Conditional on the buyer's exercising the option, the seller compares the maximal profit he can get from offering the option and investing the specified amount with what he can get without the option. The seller follows the strategy that gives him the highest profit.

Suppose that buyer and seller have an option contract p^o. After observing the seller's cost of investment $cx^2/2$, the buyer's expected utility from exercising the option in the first stage is

$$U(x, p^o) = x\beta + (1 - x) - p^o. \tag{8}$$

If the buyer does not exercise his option and instead bargains with the seller, then if $x \geq 1/\beta$, the seller will set price $p = \beta$ and the buyer gets 0 utility; and if $x < 1/\beta$, the seller will set price $p = 1$ and the buyer gets an expected utility of $x(\beta - 1)$. Hence, the condition for the buyer to exercise the option is

$$\begin{aligned} U(x, p^o) &\geq 0, \quad \text{if} \quad x \geq 1/\beta \\ U(x, p^o) &\geq x(\beta - 1), \quad \text{if} \quad x < 1/\beta \ . \end{aligned}$$

Since it is a dominated strategy to invest $0 < x < 1/\beta$, the seller will invests either more than $1/\beta$ or 0 if he offers the option contract. Let $p^o(x)$ be the largest striking price of the option the seller can set when he is going to invest $x \geq 1/\beta$: $p^o(x) = x\beta + (1 - x)$. The seller's investment then solves

$$\max_{x \geq 1/\beta} \ -\frac{cx^2}{2} + p^o(x). \tag{9}$$

Since $c < \beta(\beta - 1)$, the constraint is not binding and the solution is the efficient level $x^* = (\beta - 1)/c$, and $p^o(x^*) = x^*\beta + (1 - x^*)$. The seller's payoff for investing x^* equals $\mathcal{W}(x^*) = 1 + [(\beta - 1)]^2/(2c)$, the social welfare of efficient investment. We call $p^o(x^*)$ the efficient option contract.

Without the option contract, the seller invests $\hat{x} > x^*$ and gets profit $\hat{\Pi} = \beta^2/(2c)$, which is less than $\mathcal{W}(x^*)$. So the seller will offer the efficient option contract and invest x^*. We summarize the result in the next proposition.

Proposition 3. Under assumption 1 and when the investment is observable, the seller will offer the efficient option contract and invest x^*.

In this two-type case, the efficient investment makes the buyer get zero surplus from letting the option expire and bargaining with the seller. If the distribution of the good's value is continuous, then the buyer can guarantee himself a positive surplus from bargaining, which would lower the striking price of the option, and there might not exist an efficient option contract.

4 Conclusion

As we have seen, the usual conclusion that contract incompleteness leads to underinvestment relies on the assumption that either the investment is selfish, or the bargaining after the investment has been made is symmetric, or both. When both assumptions are violated, contract incompleteness might make the seller overinvest. In the case where the investment is unobservable, we show that there are zones of the parameters that make the seller overinvest. The intuition is that the seller cares only about the marginal contribution his investment makes to extracting the high-type buyer's surplus, while efficient investment cares about the marginal increment of average valuation. The overinvestment result can be extended to the case where the distribution of the good's value is continuous.

When the investment is observable and there is enough time between the investment and the buyer's learning the value, there is an option contract that implements the efficient outcome in the two-type case. When the investment is contractable but the price not, the mutually agreed-on investment level is efficient.

Although there have been several papers (e.g. Edlin and Hermalin, 2000) demonstrate that the relationship between contract incompleteness and underinvestment is not robust, they all assume that the bargaining is under complete information, and focus on the investment's effect on status quo and bargaining power. In this paper, we show that the underinvestment result is not robust either if the investment is cooperative and the bargaining is under asymmetric information.

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