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ABSTRACT

Can Contracts Solve the Hold-Up Problem? Experimental Evidence

In the contract-theoretic literature, there is a vital debate about whether contracts can mitigate the hold-up problem when renegotiation cannot be prevented. Ultimately, the question has to be answered empirically. As a first step in that direction, we have conducted a laboratory experiment with 490 participants. We consider "cooperative" investments that directly benefit the non-investing party. While according to standard theory, contracting would be useless if renegotiation cannot be ruled out, we find that option contracts significantly improve investment incentives compared to a no-contract treatment. This finding can be explained by Hart and Moore's (2008) notion that contracts may serve as reference points.

JEL Classification: C72, C91 and D86
Keywords: experiment, hold-up problem, option contracts and renegotiation

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1 Introduction

How to induce trading partners to make relationship-specific investments is a central theme in the contract-theoretic literature. A party may have insufficient incentives to make non-contractible investments if it fears that it will be held up by its partner in the future. This hold-up problem is an important ingredient of the incomplete contracting approach, which has become a leading paradigm in institutional and organizational economics.[1] While the possibility to solve the hold-up problem contractually has attracted broad interest in the theoretical literature, up to now there is scarce empirical evidence about the effectiveness of different contracts in inducing investment incentives. In this paper, we provide a large-scale experimental test of different contractual solutions to the hold-up problem that have been theoretically analyzed by Che and Hausch (1999). In doing so, we find evidence that supports the novel behavioral theory of Hart and Moore (2008), according to which contracts can serve as reference points.

We consider a buyer and a seller who can trade one unit of an indivisible good at some future date 2. It is always ex post efficient to trade. At date 1, the seller can make an observable but unverifiable investment that directly improves the buyer's value of the good; i.e., the investment is "cooperative" in the sense of Che and Hausch (1999). We investigate a cooperative investment because in the theoretical literature it turned out that the difficulty to find a contractual solution to the hold-up problem is particularly severe in this case.[2]

Suppose first that the parties have not written any contract before the investment stage. Then they will negotiate at date 2 in order to realize the ex post gains from trade. In this case the seller may have insufficient incentives to invest because he fears that in the negotiation process he will lose a part of the returns created by his investment. Alternatively, the parties might consider

[1] See the seminal contributions by Grossman and Hart (1986) and Hart and Moore (1990), which build on the pioneering work by Coase (1937) and Williamson (1975, 1985). Cf. Hart (1995) for a comprehensive textbook exposition.

[2] In particular, Che and Hausch (1999) have shown that in the case of cooperative investments there exists no contractual solution at all to mitigate the hold-up problem if the parties cannot commit not to renegotiate. In contrast, Edlin and Reichelstein (1996) have shown that in the case of "selfish" investments (i.e., when the investment directly benefits the investor), the first-best investment can be induced by a suitable contract even if renegotiation cannot be ruled out.

to write a fixed-price contract at an initial date 0. However, if this contract specifies that the buyer has to purchase the good from the seller for a fixed price at date 2, then the seller has no investment incentives at all, because his revenue is independent of his investment. But the underinvestment problem can be solved if the parties write a simple option contract at date 0, provided that they can commit not to renegotiate the contract. The idea is that the option contract specifies a strike price such that the buyer will exercise the option only if the seller has chosen the first-best investment level. Anticipating the buyer's behavior, the seller will actually choose the first-best investment level, provided that the strike price at least covers his investment costs. However, if renegotiation cannot be ruled out, the buyer might prefer not to exercise the option, because he anticipates that the ex post inefficient no-trade decision will be reversed and that through renegotiations he will obtain a larger share of the gains from trade. The seller in turn anticipates the buyer's behavior and hence he has the same investment incentives as if there were no contract at all. Note, however, that these predicted investment decisions in the different scenarios are derived under the assumption that buyer and seller are rational and have standard preferences (i.e., they are interested in their monetary payoffs only).

In our experiment, we study the investment behavior in these four scenarios (no contract, fixed-price contract, option contract, option contract with renegotiation) in four different treatments. We consider a seller who can choose between a low and a high investment, where the high investment level is first-best. Taking into consideration the results from previous experimental studies investigating the hold-up problem, we know that investments are typically not perceived as sunk,[3] and the behavior of a relevant fraction of subjects is in line with inequity-aversion.[4] This suggests for our experiment that even in the no-contract treatment (which serves as a benchmark), at least some sellers will choose the high investment level because they hope to be rewarded for their investment by the buyer such that their net profit from high investment is larger than their net profit from low investment. The main focus of our

[3]Hackett (1993) strongly rejects the hypothesis that realized surplus shares are independent of sunk investments. See also Ellingsen and Johannesson (2004a,b), who find that a relevant share of sellers invests even if there is the possibility to be held up in the future.

[4]For two leading models of inequity aversion, see Fehr and Schmidt (1999) and Bolton and Ockenfels (2000). See also the surveys by Fehr and Schmidt (2003, 2006) for extensive discussions of these and further models of other-regarding preferences.

experimental study is to empirically assess whether contractual arrangements can improve investment incentives compared to the no-contract case.

In particular, our experimental results suggest that a fixed-price contract indeed cannot improve investment incentives compared to the no-contract case. Moreover, as predicted by standard theory, the option contract when renegotiation can be ruled out is very effective in inducing high investments. If renegotiation cannot be ruled out, the option contract becomes less effective; i.e., the share of sellers who choose high investment decreases, but it is still significantly larger than in the no-contract case. Hence, in contrast to what is suggested by standard theory, even if renegotiation cannot be ruled out, an option contract *does* have a significant impact on investment incentives.

High investments in the no-contract treatment, the fixed-price treatment, and the option contract with renegotiation treatment can be explained by inequity aversion. However, the observed difference in investment behavior between the no-contract treatment and the option contract with renegotiation treatment cannot be explained by inequity aversion. This is because in models of inequity aversion, only the allocation of final payoffs matters, and with regard to these two treatments, the attainable allocations of final payoffs are the same. Hence, if inequity aversion was the driving force behind the subjects' behavior, the fractions of high investment should be about the same in both treatments.

However, the fact that in the option contract with renegotiation treatment sellers invest significantly more than in the no-contract treatment can be explained if the behavioral assumptions of Hart and Moore (2008) apply. Their central idea is that contracts may serve as reference points for trading relationships. In other words, an ex ante contract may shape the parties' feelings of entitlement with regard to ex post outcomes. Hart and Moore (2008) argue that a party which ex post does not get what it feels entitled to will be aggrieved and may be willing to punish its trading partner, even if this is costly and yields no material gain. For our option contract with renegotiation treatment, this may imply that a seller who has chosen high investment may feel entitled to the strike price. A seller who feels entitled to the strike price specified in a mutually agreed upon option contract may well be aggrieved if the option is not exercised even though investment was high. This aggrievement may make the seller more inclined to turn down offers below the strike price. Indeed, in our experiment it turned out that a large share of buyers actually

exercised the option if investment was high, which may indicate that buyers anticipate the sellers' feelings of entitlement.

Our paper brings together two different strands of literature. First, our prime motivation stems from Che and Hausch's (1999) important insight that in the case of "cooperative" investments, contracting may have no value at all if renegotiation cannot be prevented. The question whether clever contractual arrangements such as option contracts can mitigate or even solve the hold-up problem has been discussed intensively in the contract-theoretic literature. Building on Maskin and Moore (1999), several authors have argued that renegotiation undermines the ability of any conceivable contract to create investment incentives (see e.g. Hart and Moore, 1999, Segal, 1999, and Segal and Whinston, 2002). In contrast, other authors such as Nöldeke and Schmidt (1995, 1998) and Lyon and Rasmusen (2004) are more optimistic about the possibility to solve the hold-up problem with suitable option contracts.[5] While the debate in the theoretical literature is focused on details of the renegotiation game (e.g., whether or not the option can still be exercised after a renegotiation offer has been turned down), our experiment suggests that writing option contracts can have a value even in a setting where the renegotiation process is such that according to standard theory option contracts would be useless.

Second, our paper provides further evidence for Hart and Moore's (2008) recent behavioral theory that contracts may serve as reference points.[6] They focus on the trade-off between rigid and flexible contracts in a setting with ex ante uncertainty about the state of nature. A rigid contract specifies a price at which trade will occur. While trade takes place in the good state only, the parties get what they expect, so there is no reason for aggrievement. A flexible contract determines a price range only, so that trade may take place also in the bad state of the world, but aggrievement and costly punishment may occur if a party gets less than it had hoped for. Fehr, Hart, and Zehnder (2008a) find experimental evidence that largely confirms the novel theory. However, they consider neither non-contractible investments nor renegotiation, on which we

[5] See also Hart and Moore (1988), Chung (1991), Rogerson (1992), Hermalin and Katz (1993), Aghion, Dewatripont, and Rey (1994), Edlin and Reichelstein (1996), Bernheim and Whinston (1998), Maskin and Tirole (1999), Tirole (1999), Edlin and Hermalin (2000), MacLeod (2002), Wickelgren (2006), Watson (2007), and Ohlendorf (2009) for further contributions to this vital debate.

[6] See also Hart and Moore (2007) and Hart (2008, 2009).

focus in our experiment. In particular, to the best of our knowledge, there is not yet any experimental evidence that option contracts may serve as reference points and thereby help to mitigate the hold-up problem.

The remainder of the paper is organized as follows. In the next section, to motivate our experiment, we present the theoretical framework as a starting point. In section 3, we describe the experimental design. In section 4, we discuss the qualitative hypotheses to be tested. Section 5 summarizes the results and section 6 concludes.

2 The theoretical framework

Consider a seller and a buyer who can trade one unit of an indivisible good at some future date 2. At date 1, the seller can make a relationship-specific investment $e \in \{e_l, e_h\}$, which is measured by its costs. The investment increases the buyer's value $v(e) > 0$ from consuming the good. The seller incurs no further costs at date 2. Hence, the first-best outcome is achieved if at date 2 trade occurs and at date 1 the investment level $e^* = \arg\max v(e) - e$ is chosen. Assume that $e_l < e_h$, $v(e_l) < v(e_h)$, and $v(e_h) - e_h > v(e_l) - e_l > 0$, i.e. high investment is first-best. When the parties agree on a contract at an initial date 0, it is their common interest to implement high effort, because they can divide the total surplus by suitable lump-sum payments.

No contract. As a benchmark, suppose first that no contract can be written before the investment stage. If at date 2 the parties split the surplus $v(e)$ according to the generalized Nash bargaining solution, then at date 1 the seller invests $e^{NC} = \arg\max \alpha v(e) - e$, where α denotes the seller's bargaining power. If the seller's bargaining power is sufficiently small, so that $\alpha v(e_h) - e_h < \alpha v(e_l) - e_l$, then $e^{NC} = e_l < e^* = e_h$, i.e. there is underinvestment. This means that a hold-up problem occurs, which raises the question whether suitable contractual arrangements can improve the seller's investment incentives.

Fixed-price contract. Suppose that at date 0 the parties sign a contract that simply specifies a price p at which trade has to occur at date 2. Then the seller's date-1 profit is $p - e$, so that he will choose $e = e_l$. Compared to the no-contract setting, the fixed-price contract cannot enhance the seller's incentives to invest.

Option contract. Suppose that at date 0 the parties sign a contract according

to which the buyer has the option to purchase the good at a strike price p at date 2. Consider a price p such that $v(e_l) < p < v(e_h)$. Then the buyer exercises the option if and only if $e = e_h$. Hence, the seller invests e_h, provided that $p - e_h > 0$. Note that a suitable price p can always be found because $\max\{e_h, v(e_l)\} < v(e_h)$. Thus, the first-best outcome can be achieved with an option contract. However, this conclusion crucially relies on the assumption that the opportunity to trade is irretrievably forgone once the buyer has not exercised the option; i.e., the parties can commit not to renegotiate.

Option contract with renegotiation. Suppose that the parties sign an option contract, but they cannot commit not to renegotiate. If the buyer decides not to exercise the option, then an ex post inefficiency would occur. In this case, since renegotiation cannot be ruled out, at date 2 the parties will agree on trade by bargaining, and hence split the surplus $v(e)$ as in the no-contract case. Anticipating renegotiation, the buyer will not exercise the option if $v(e) - p < (1 - \alpha)v(e)$. Hence, the seller's date-1 profit is $\min\{p, \alpha v(e)\} - e$. Note that the best the parties can do is to agree on a price $p \geq \alpha v(e_h)$, so that the seller has the same investment incentives as in the no-contract case, $e = e^{NC}$.

3 Design

Our experiment consists of four different treatments. Each treatment was run in four sessions. Each session had 32 participants, except for two sessions with 28 subjects and one session with 18 subjects. No subject was allowed to participate in more than one session. In total, 490 subjects participated in the experiment. All subjects were students of the University of Cologne from a wide variety of fields of study. The computerized experiment was programmed and conducted with zTree (Fischbacher, 2007) and subjects were recruited using ORSEE (Greiner, 2004). A session lasted between 20 and 30 minutes. Subjects were paid on average 13.25€.[7]

In each session, half of the participants were randomly assigned to the role of sellers and the others to the role of buyers. Each seller was randomly matched with one buyer. In order to give subjects a monetary incentive to take

[7] To ensure non-negative payoffs, in addition to the profit made in the experiment, all subjects were paid a participation fee of 8€.

their decisions seriously and to ensure a large number of independent observations, each session consisted of only one round; i.e., there were no repetitions and this was known to the subjects. All interactions were anonymous; i.e., no subject knew the identity of its trading partner. At the beginning of each session, written instructions were handed out to each subject.

In each treatment, the seller can invest either $e_l = 0$€ or $e_h = 8$€ and thereby the seller influences the buyer's value from consumption of the good. Depending on the seller's investment decision, the buyer's value is either $v(e_l) =$ 10€ or $v(e_h) = 22$€.

No contract (NC) treatment. There are three stages. In the first stage, the seller makes the investment decision $e \in \{0€, 8€\}$. In the second stage, the buyer learns how much the seller has invested; i.e., the buyer learns his valuation $v(e)$. Then the buyer can make a take-it-or-leave-it offer to the seller; i.e., he offers a price p at which he is willing to buy the good (where p can be any integer between zero and the buyer's valuation). In the third stage, the seller decides whether he wants to sell the good to the buyer at price p. If the seller accepts the offer, the seller's profit is $p - e$ and the buyer's profit is $v(e) - p$. If the seller rejects the offer, the seller's profit is $-e$ and the buyer makes zero profit.

Fixed-price contract (FP) treatment. There are up to two stages. In the first stage, the seller and the buyer can decide whether or not to accept the following contract: "Seller and buyer agree contractually, that the buyer will purchase the good at price $p = 15$€ in stage 2." If one or both parties do not accept the contract, the experiment is over and each party makes zero profit, while stage 2 follows if both parties accept the contract. In the second stage, the seller makes the investment decision $e \in \{0€, 8€\}$. The parties' profits then follow immediately from the contract and the seller's investment decision. Specifically, the seller's profit is 15€$-e$ and the buyer's profit is $v(e) - 15$€.

Option contract (OC) treatment. There are up to three stages. In the first stage, the seller and the buyer can decide whether or not to accept the following contract: "The buyer has the option to buy the good at price $p = 15$€ in stage 3." If one or both parties do not accept the contract, the experiment is over and each party makes zero profit, while stage 2 follows if both parties accept the contract. In stage 2, the seller makes the investment decision $e \in \{0€, 8€\}$.

In stage 3, the buyer learns how much the seller has invested and then he can decide whether or not to exercise the option. If the option is exercised, the seller's profit is 15€$-e$ and the buyer's profit is $v(e) - 15$€. If the option is not exercised, the seller's profit is $-e$ and the buyer makes zero profit.

Option contract with renegotiation (OCR) treatment. There are up to five stages. The first three stages are as in the OC treatment, except that the consequences of not exercising the option in stage 3 are different now. If the buyer has not exercised the option, then stage 4 follows. In stage 4, the buyer can make a take-it-or-leave-it offer to the seller; i.e., he offers a price p at which he is willing to buy the good (where p can be any integer between zero and the buyer's valuation). In stage 5, the seller decides whether he agrees to trade the good at price p. If the seller accepts the offer, the seller's profit is $p - e$ and the buyer's profit is $v(e) - p$. If the seller rejects the offer, the seller's profit is $-e$ and the buyer makes zero profit.

4 Qualitative hypotheses

No contract. In our experimental setup the seller's bargaining power α is equal to zero, which makes the hold-up problem most severe. The standard theoretical prediction would be that after the investment is sunk, the buyer offers the seller a price $p = 0$€, which the seller would accept. Anticipating the fact that the buyer will not compensate the seller for his investment, the seller chooses the low investment level $e_l = 0$€. However, it has been shown in numerous experimental studies of the ultimatum game,[8] that subjects often reject offers that give them only a small fraction of the pie to be divided and proposers offer a substantial share of the pie.[9] Moreover, experimental studies investigating hold-up problems have shown that investments are typically not perceived as sunk (Hackett, 1993; Ellingsen and Johannesson, 2004a,b). This implies for our experiment that the buyer may reward the seller for his high

[8] On the ultimatum game, see Güth, Schmittberger, and Schwarze (1982); see also Camerer (2003) for an extensive survey.

[9] Nevertheless, as long as the investment is regarded as sunk at date 2 (i.e., the pie to be divided is $v(e)$), sellers should still choose the low investment in our setup. If the seller believes that he will get the fraction $\hat{\alpha}$ of the pie, his profit is $10\hat{\alpha}$ given low investment and $22\hat{\alpha} - 8$ given high investment; i.e., high investment would be more profitable only if the seller believes to get more than 2/3 of the pie, which seems to be implausible.

investment by making an offer such that the net profit of the seller from high investment is larger than the net profit from low investment. The behavior of buyers who offer more than what is predicted by standard theory is often explained by inequity aversion.

As a consequence, we might expect that some sellers will choose low investments because of the fear to be held up while other sellers may hope to be rewarded for high investment and thus choose e_h. We are particularly interested in the relation between high and low investments in the NC treatment as a benchmark in order to empirically assess whether there are contractual arrangements that improve the incentives to invest.

Fixed-price contract. With regard to a fixed-price contract, the standard theoretical prediction would be that for any given price p, the seller will choose the low investment level e_l. This implies that a buyer would never agree to such a contract if $p > v(e_l) = 10$€. However, note that the strategic situation resembles a gift-exchange game.[10] There is by now ample experimental evidence that in such games agents reward a principal who offers them a large fixed wage by exerting high effort. Similarly, in our setting a buyer may accept a fixed-price contract with $p > 10$€, because he believes that the seller will reward him for doing so by choosing the high investment level e_h. A common explanation for the subjects' behavior in gift-exchange games is inequity-aversion.[11] Hence, in our experiment we have set $p = 15$€, because then the high investment level may well be attractive for an inequity-averse seller (given $p = 15$€, if the seller chooses e_h, then both parties' net profits are 7€). Buyers who believe that they are matched with an inequity-averse seller who will choose e_h may thus accept the contract (such that both parties would make a profit of 7€ instead of zero). A smaller price would make high investment less likely even if sellers are inequity-averse, while a larger price would make rejection of the contract by buyers more likely. Hence, the price $p = 15$€ seems to be the one that gives the fixed-price contract the best chance to be accepted and to induce high investment.

Nevertheless, we hypothesized that in the FP treatment, high investments would not occur more often than in the NC treatment. We expected a substantial fraction of buyers to reject the contract and we thought that in both treatments positive investments may have the same reason (i.e., inequity aversion).

[10] On gift exchange, see Akerlof (1982) and Fehr, Kirchsteiger, and Riedl (1993, 1998).

[11] See Fehr and Schmidt (1999, section VI).

Hence, in accordance with standard theory, we expected that a fixed-price contract cannot mitigate the hold-up problem.

Hypothesis 1. In the FP treatment, given that the fixed-price contract is accepted, the share of sellers who invest high is about the same as in the NC treatment.

Option contract. If renegotiation can be ruled out, standard theory predicts that the first-best outcome is achieved by an option contract with strike price $p \in [10€, 22€]$. In order to compare the effectiveness of the option contract with the fixed-price contract, we have again chosen $p = 15€$. Since high investment then also leads to an equitable outcome, we hypothesized that the first-best outcome will almost always be achieved.[12]

Hypothesis 2. In the OC treatment, investment incentives will be much higher than in the NC (and the FP) treatment.

Option contract with renegotiation. If renegotiation cannot be ruled out, standard theory predicts that an option contract cannot improve investment incentives compared to the no-contract case. The reason is that the buyer would never exercise the option but instead he would subsequently make a take-it-or-leave-it offer to the seller, such that the seller would choose e_l because of the fear to be held up. We hypothesized that indeed the fear to be held up would result in less investments compared to the OC treatment.

Hypothesis 3. In the OCR treatment, the investment incentives are lower than in the OC treatment.

However, for the same reasons as in the no-contract case, we did not expect all sellers to choose the low investment level. In particular, high investments may again be explained by sellers who expect to meet inequity-averse buyers. Hence, one hypothesis would be that investments would not differ significantly between the OCR treatment and the NC treatment, because inequity aversion cannot explain different investment behaviors in these two treatments.

Hypothesis 4a. There is no difference in investment levels between the OCR treatment and the NC treatment.

Hence, Hypothesis 4a would be in line with the standard theoretical prediction (in the spirit of Che and Hausch, 1999). An alternative hypothesis would

[12] We expected that in the OC and OCR treatments, only a negligible fraction of subjects would reject the option contract, because the buyer could only gain, and the seller could also gain and at least ensure zero profits by not investing.

be that given an option contract has been signed, there are more investments than in the NC treatment, even if the parties cannot commit not to renegotiate. The explanation could be that the option contract serves as a reference point, so that sellers feel entitled to get the payment of 15€ when they invest high. According to this hypothesis, buyers would exercise the option or at least make an offer that does not deviate too much from 15€, because they fear that otherwise the seller would reject their offer.[13]

Hypothesis 4b. The average investment level in the OCR treatment is larger than the one in the NC treatment.

It is a main objective of our study to find out whether there is empirical support for either Hypothesis 4a or Hypothesis 4b; i.e., whether or not the possibility of renegotiation completely undoes the investment-inducing effect of an option contract.

5 Results

In this section we describe and analyze our results. Figure 1 shows for all treatments how much has been invested and in how many cases the proposed contract was rejected. In accordance with our qualitative hypotheses derived from previous experimental work, the observed investment levels in the NC treatment show that not all sellers choose zero investment, but that there is a relevant share of sellers (35.5%) who prefer to invest high. With regard to the FP treatment, we find that the contract was rejected in 28.1% of the cases. It is interesting to note that in all cases in which the contract was not accepted, it was always the buyer who rejected it, which is in accordance with standard theory. Given that the fixed-price contract was accepted, 32.6% of the sellers chose the high investment level.

Furthermore, it is immediate to see that if renegotiation can be ruled out, an option contract is highly effective in inducing investment incentives. The contract was always accepted and there was high investment in 90.9% of the cases. In the OCR treatment, where renegotiation cannot be ruled out, the option contract was rejected in 6.3% of the cases. Conditional on acceptance of the contract, 71.7% of the sellers chose the high investment level.

[13] Note that rejecting the offer is a form of costly punishment and thus corresponds to a "shading" activity in Hart and Moore (2008).

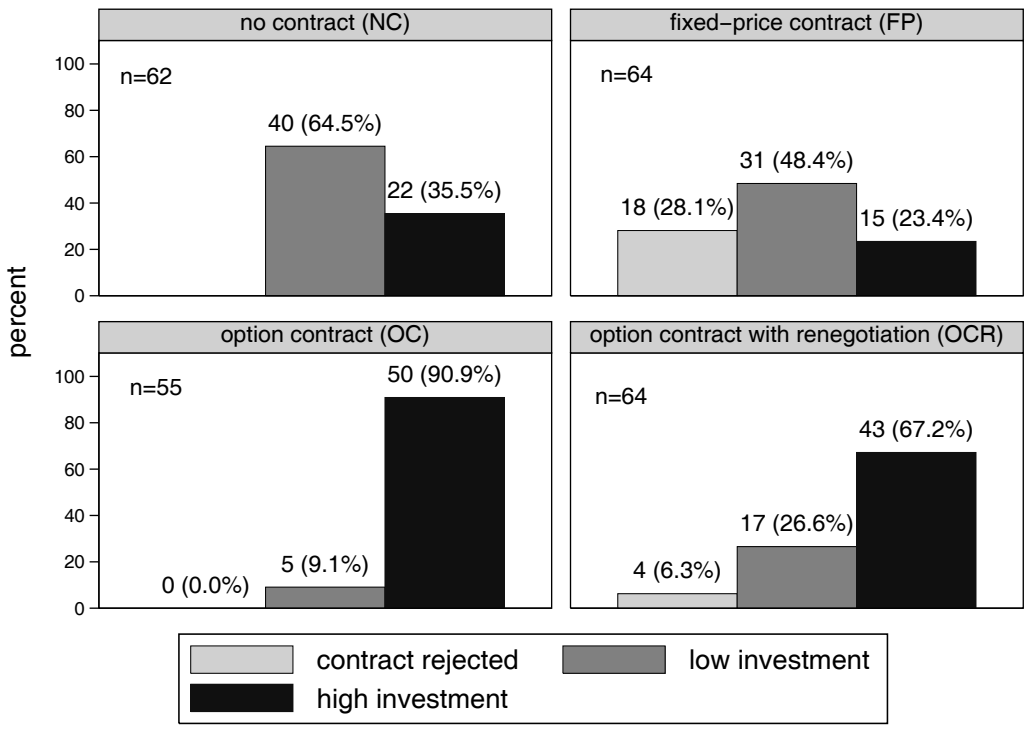

Figure 1. Contract rejections and investment behavior (n denotes the number of seller-buyer pairs in each treatment).

Table 1 reports significance levels with regard to the differences in investment behavior between the treatments. The investment levels in the NC treatment and the FP treatment do not differ significantly. In other words, we cannot reject Hypothesis 1. In both treatments, high investments can be explained by inequity aversion, while the fact that a fixed-price contract cannot improve investment incentives compared to the no-contract case is qualitatively in accordance with standard theoretical predictions. Compared to a fixed-price contract and the no-contract setting, if renegotiation can be ruled out, an option contract leads to an extreme improvement in investment incentives which is highly significant. This result strongly supports Hypothesis 2. In line with the theoretical prediction, if it is possible to prevent renegotiation, then indeed an option contract is very effective in mitigating the underinvestment problem.

In the OCR treatment, the chosen investment levels are significantly lower than in the OC treatment, which is in line with Hypothesis 3. This finding provides empirical evidence for the standard theoretical argument that subjects fear to be held-up when renegotiation is possible; i.e., there is a hold-up problem. On the other hand, even if renegotiation cannot be ruled out, it is

highly significant that there is more investment if the parties have agreed on an option contract than if there is no contract at all. Hence, we can clearly reject Hypothesis 4a, while we find support for Hypothesis 4b.

	NC vs. FP	NC vs. OC	FP vs. OC	OC vs. OCR	FP vs. OCR	NC vs. OCR
all observations	0.1718	< 0.0001	< 0.0001	0.0018	< 0.0001	0.0006
cond. on contr.	0.8387	< 0.0001	< 0.0001	0.0097	< 0.0001	< 0.0001

Table 1. Significance levels for pairwise comparisons of investment behavior between the treatments. The table reports the p-values according to two-sided Fisher exact tests. In the first row, all observations are taken into consideration, while in the second row, in the FP and OCR treatments only those seller-buyer pairs that accepted the contract are considered.

Observe that in the NC treatment and the OCR treatment the buyer has the same possibilities with regard to his price offer, except that in the OCR treatment he first has to decide not to exercise the option. Moreover, the only difference between exercising the option in the OCR treatment and offering a price $p = 15$€ in the NC treatment is that a seller can reject the offer in the latter case; but regardless of the investment level, rejecting an offer of $p = 15$€ is extremely implausible (in fact, an offer of 15€ was never rejected). Hence, neither selfish behavior nor behavior that is driven by inequity aversion can explain why sellers behave differently in the two treatments.[14] Given a seller's expectation about the type of buyer he is going to meet, the seller should choose the same investment level in both treatments.

But in the OCR treatment, sellers choose high investment more often, which can be explained if the option contract is perceived as a reference point

[14] Note that the different behavior in the NC and OCR treatments also cannot be explained by (intention-based) reciprocity models (e.g., Rabin, 1993; Charness and Rabin, 2002), which assume that if different outcomes are available in different treatments, then this may trigger different fairness perceptions. However, in the two treatments the same outcomes are available, so that fairness perceptions should not differ between the treatments. (See also the related discussion in Fehr, Hart, and Zehnder, 2008a, section V.)

as suggested by Hart and Moore (2008).[15] Given that the parties agreed on the contract, sellers might feel entitled to the strike price when they choose the high investment level. Buyers might then actually exercise the option (or make a price offer not too much below the strike price), because they fear that otherwise the seller might be aggrieved and reject the offer.

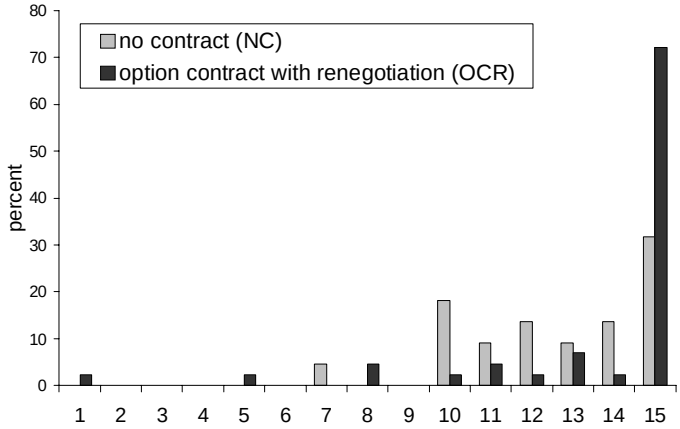

Figure 2. The prices at which buyers were willing to buy, given high investment. Implausible offers larger than 15€ did not occur. Note that in the NC treatment, only 45.5% of the buyers offered 14€ or 15€, while in the OCR treatment the option was exercised by 72.1% of the buyers. The average price at which a buyer was willing to buy was 13.58€ in the OCR treatment and 12.64€ in the NC treatment. The difference is statistically significant (p-value=0.0076, two-sided Mann-Whitney U test).

Indeed, given that the high investment level was chosen, 72.1% of the buyers exercised the option in the OCR treatment, while only 31.8% of the buyers

[15] Note that Ellingsen and Johannesson (2004a,b) and Charness and Dufwenberg (2006, 2008a) experimentally confirmed that free-form, personalized statements-of-intent can enhance cooperative behavior. Yet, Charness and Dufwenberg (2008b) found that impersonal, bare messages (i.e., indicating whether or not to make a promise to play cooperatively) are ineffective. In our experiment, both parties only had to indicate whether or not they agree to the contract, but there was no personal, free-form communication. Hence, we have isolated the effect of a mutually agreed-upon contract from the effect of personalized communication. On deception and misrepresentation of intentions, see also Crawford (2003) and Gneezy (2005).

offered a price of 15€ in the NC treatment. Given high investments, Figure 2 illustrates for the NC and OCR treatments the distributions of prices at which buyers were willing to buy (i.e., the strike price if the option was exercised in the OCR treatment or otherwise the offer made to the seller). Obviously, the option contract influences the buyers' perception of how much the sellers are supposed to get.

The average price at which trade occurs supports this finding, too. Figure 3 shows that given high investment, the average price at which trade occurs is significantly larger in the OCR treatment than in the NC treatment.[16] Moreover, Figure 3 shows that given low investment, the average price at which trade occurs is smaller in the OCR treatment than in the NC treatment. Though this difference is not significant, one may argue that the direction is consistent with the reference point hypothesis. Once the option contract is signed, the buyer may expect the seller to invest high and if he does not, the buyer may be aggrieved and hence make a smaller offer than if there were no contract.

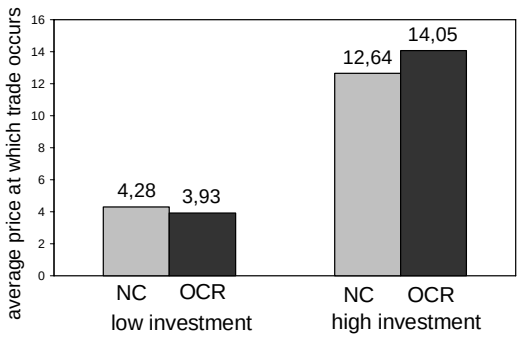

Figure 3. The average price at which trade occurs. Given high investment, the difference is statistically significant (p-value=0.0012, two-sided Mann-Whitney U test).

[16] Note that given high investment, in the OCR treatment the average trade price (14.05€) is larger than the average price at which a buyer was willing to buy (13.58€), because three offers were rejected in the OCR treatment (while no rejections occurred in the NC treatment). The fact that sellers who have chosen the high investment level turned down the buyers' offers more often in the OCR treatment (when the option was not exercised) than in the NC treatment again is in line with the reference point hypothesis (i.e., the sellers felt entitled to the price of 15€ and were aggrieved when the option was not exercised).

Figure 4 summarizes the presented results and additionally illustrates how often ex post inefficiencies occurred and how the total surplus was split among buyers and sellers in the different treatments. In the four panels, the upper curve represents different combinations of the parties' profits given high investment; i.e., different locations of the circles along this curve mark different splits of the total surplus of 14€. Similarly, the lower curve indicates different combinations of profits given low investment, such that the total surplus is 10€.

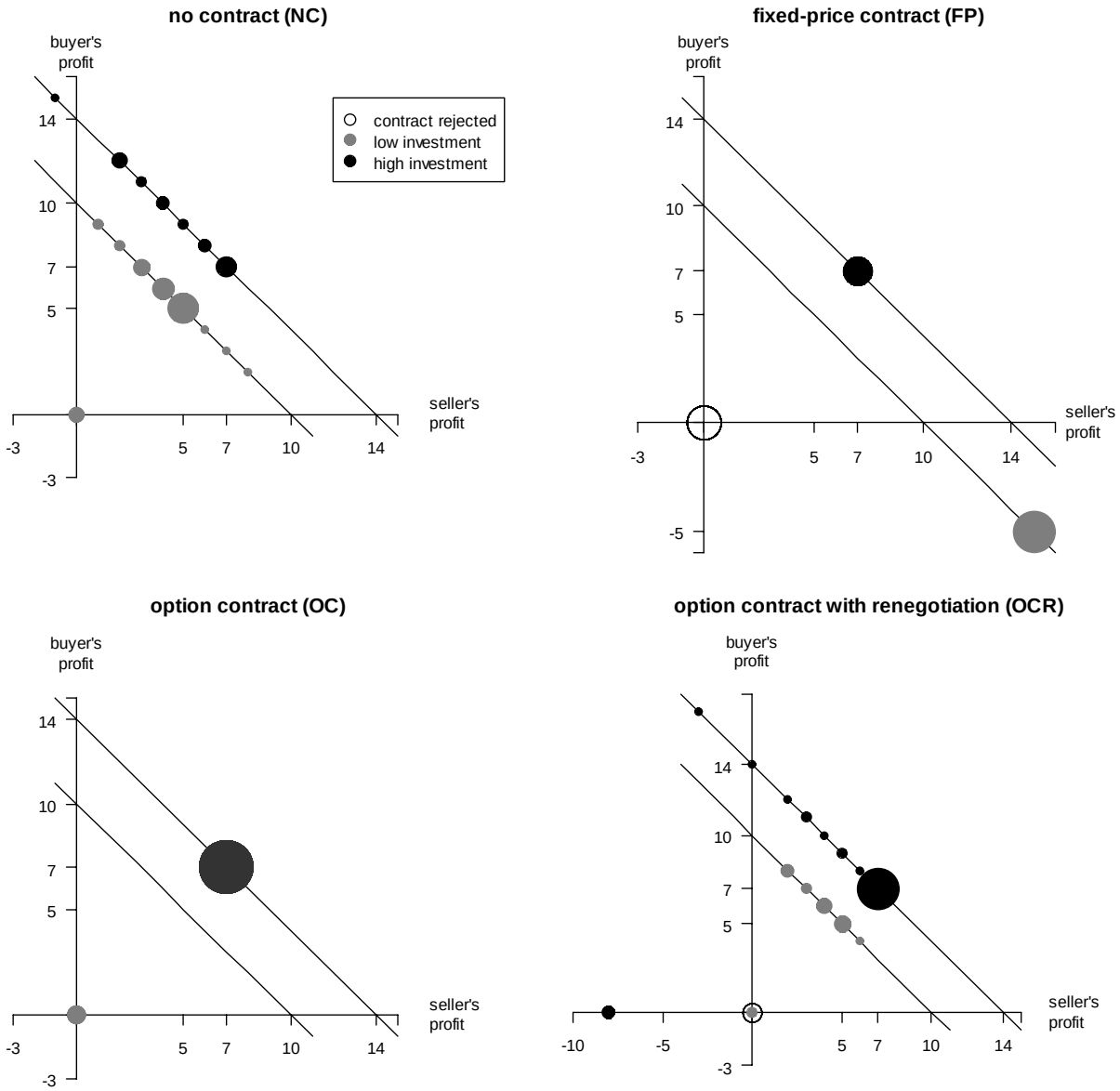

Figure 4. Profits of sellers and buyers in the four treatments. The size of the circles represents the number of observations.

Consider the NC treatment. Observe that given high investment, no bargaining inefficiencies occurred, while given low investment, four offers were rejected, such that both parties made zero profits. The sellers' average profit was 4.64€ given high investment, while it was 3.85€ given low investment. While thus it was on average profitable for a seller to choose the high investment level, it should be noted that the difference is not statistically significant.

Next, consider the FP treatment. The circle in the origin represents the 28.1% of the cases in which the contract was rejected by the buyer. It is immediate to see that given the contract was signed, the majority of sellers (67.4%) chose low investment. As a result, the average profit of the buyers who accepted the contract was −1.09€, while they could make zero profit by simply rejecting the contract. The difference is statistically significant (p-value= 0.0202, two-sided Mann-Whitney U test). Hence, rejecting the contract as recommended by standard theory was the more profitable strategy for buyers.

In the OC treatment, in all of the 90.9% of the cases in which the high investment level was chosen the option was actually exercised. When the investment was low, the option was never exercised.

Finally, consider the OCR treatment. The contract was rejected in 6.3% of the cases, as indicated by the circle in the origin. Comparing the panels that illustrate the NC and OCR treatments, one sees immediately that even if renegotiation cannot be ruled out, the option contract strongly influences the split of the surplus given high investment. In accordance with the reference point hypothesis, the by far biggest circle in the OCR panel corresponds to the case in which the strike price was paid.

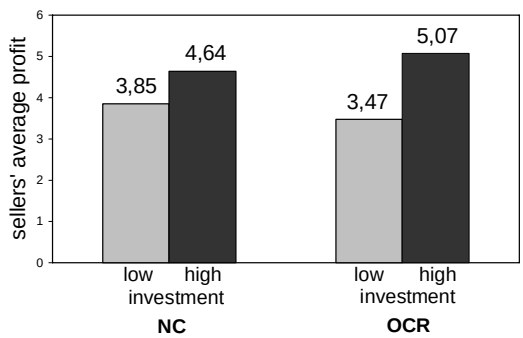

Figure 5. The sellers' average profits in the NC and OCR treatments. While high investment is more profitable than low investment in both treatments, the difference is statistically significant in the OCR treatment only (p-value<0.0001, two-sided Mann-Whitney U test).

As is illustrated in Figure 5, the seller's average profit in the OCR treatment was 5.07€ given high investment, but it was only 3.47€ given low investment. Hence, it was more profitable for sellers to invest high. In contrast to the NC case, this difference is highly significant. In line with the reference point hypothesis, the fact that an option contract was signed clearly improves the sellers' incentives to choose high instead of low investment.

6 Concluding remarks

The question whether or not suitable contracts can solve or at least mitigate the hold-up problem when renegotiation cannot be prevented has been at the center of a long-lasting and controversial debate in the contract-theoretic literature. In this paper, we make a first step to address this important question in the laboratory. Our experimental results indicate that option contracts can be quite effective, even in a setting in which standard theory suggests that it is particularly hard to induce investments. Specifically, we consider cooperative investments in the sense of Che and Hausch (1999) and a specification of the renegotiation game which would make contracting completely redundant according to standard theory. The fact that option contracts trigger investment incentives despite the possibility of renegotiation can be explained by the novel theory of Hart and Moore (2008), who argue that contracts may serve as reference points. Yet, their focus is on the trade-off between rigid and flexible contracts in the absence of non-contractible investments.

In a recent experimental study, Fehr, Hart, and Zehnder (2008b) have shown that in their setting, a rigid contract is perceived as a salient reference point only if its terms are determined in a competitive way, while their findings for flexible contracts do not depend on whether the terms are negotiated in a competitive market. In our OCR treatment the option contract is a flexible contract in the sense that it allows both parties to trade profitably regardless of how much the seller has invested and it gives the buyer the possibility to influence the final trade price after the seller's investment decision has been made. However, while in Fehr, Hart, and Zehnder (2008b) their flexible contract determines a price range only, our option contract makes one particular price (i.e., the strike price) salient, a feature that it has in common with rigid contracts in their setting. But in our experiment, option contracts serve as reference points, even though they are not concluded in a competitive mar-

ket. Note, however, that in contrast to Fehr, Hart, and Zehnder's (2008b) no-competition setting, in our experiment the parties were explicitly asked whether or not they wanted to sign the contract. The fact that they deliberately agreed to the contract might strengthen their perception of the strike price as the salient reference point.

Moreover, the fact that given high investment the strike price allowed the parties to share the total surplus evenly, might have had a positive effect on the parties' willingness to accept the price as a reference point. It might be an interesting avenue for future research to investigate whether ex ante competition may further increase the parties' readiness to accept the strike price as a reference point, in particular if the strike price were such that exercising the option would lead to an unequal split of the surplus (possibly accompanied by suitable lump-sum payments). Furthermore, in future research we plan to experimentally assess the effectiveness of option contracts for different renegotiation games and settings where investments directly affect the investing party. Thereby, we hope to shed further light on the important question under which circumstances contracts can help to mitigate hold-up problems by serving as reference points.

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Appendix

The following instructions were handed out to the participants in the NC treatment:

<u>Experimental Instructions</u>

In this experiment there is always one seller who interacts with one buyer. You are randomly assigned either to the role of the seller or to the role of the buyer.

The experiment consists of only one single period.
The period consists of three stages.

Stage 1:
On the screen you can see whether you have been assigned to the role of the seller or to the role of the buyer.

The seller can make an investment decision. He can invest either 0 € or 8 € and thereby he can influence the buyer's valuation for a particular good which can be traded later.

If the seller has invested 0 €, then the buyer's valuation for the good is 10 €.
If the seller has invested 8 €, then the buyer's valuation for the good is 22 €.

Stage 2:
The buyer learns the seller's investment decision and so now he knows his valuation. Then the buyer can make an ultimate price offer p to the seller at which the buyer is willing to buy the good. (The price has to be an integer between zero and the buyer's valuation for the good.)

Stage 3:
The seller can decide whether he wants to sell the good to the buyer at the offered price p.

At the end of stage 3, the profits are as follows.

If the seller has invested 0 €:

- If the seller has accepted the offer:
  Seller's profit: p € - 0 € = p €
  Buyer's profit: 10 € - p €
- If the seller has not accepted the offer:
  Seller's profit: 0 €
  Buyer's profit: 0 €

If the seller has invested 8 €:

- If the seller has accepted the offer:
  Seller's profit: p € - 8 €
  Buyer's profit: 22 € - p €
- If the seller has not accepted the offer:
  Seller's profit: -8 €
  Buyer's profit: 0 €

The following instructions were handed out to the participants in the FP treatment:

Experimental Instructions

In this experiment there is always one seller who interacts with one buyer. You are randomly assigned either to the role of the seller or to the role of the buyer.

The experiment consists of only one single period.
The period consists of up to two stages.

Stage 1:
On the screen you can see whether you have been assigned to the role of the seller or to the role of the buyer.

Both the seller and the buyer can decide whether or not they agree to the following contract:

„Seller and buyer agree contractually, that the buyer purchases a particular good at the price of 15 € at the end of stage 2."

If one or both parties do not agree to the contract, the experiment is over. Then each party makes a profit of 0 €.

If both parties agree to the contract, then stage 2 follows.

Stage 2:
The seller can make an investment decision. He can invest either 0 € or 8 € and thereby he can influence the buyer's valuation for the good.

If the seller has invested 0 €, then the buyer's valuation for the good is 10 €.
If the seller has invested 8 €, then the buyer's valuation for the good is 22 €.

At the end of stage 2, the profits result from the signed contract and the investment decisions.

If the seller has invested 0 €:
Seller's profit: 15 € - 0 € = 15 €
Buyer's profit: 10 € - 15 € = -5 €

If the seller has invested 8 €:
Seller's profit: 15 € - 8 € = 7 €
Buyer's profit: 22 € - 15 € = 7 €

The following instructions were handed out to the participants in the OC treatment:

<u>Experimental Instructions</u>

In this experiment there is always one seller who interacts with one buyer. You are randomly assigned either to the role of the seller or to the role of the buyer.

The experiment consists of only one single period.
The period consists of up to three stages.

Stage 1:
On the screen you can see whether you have been assigned to the role of the seller or to the role of the buyer.

Both the seller and the buyer can decide whether or not they agree to the following contract:

„The buyer has the option to purchase a particular good at the price of 15 € in stage 3."

If one or both parties do not agree to the contract, the experiment is over. Then each party makes a profit of 0 €.

If both parties agree to the contract, then stage 2 follows.

Stage 2:
The seller can make an investment decision. He can invest either 0 € or 8 € and thereby he can influence the buyer's valuation for the good.

If the seller has invested 0 €, then the buyer's valuation for the good is 10 €.
If the seller has invested 8 €, then the buyer's valuation for the good is 22 €.

Stage 3:
The buyer learns the seller's investment decision and so now he knows his valuation. Then the buyer can exercise the option.

At the end of stage 3, the profits are as follows.

If the seller has invested 0 €:

- If the buyer has exercised the option:
  Seller's profit: 15 € - 0 € = 15 €
  Buyer's profit: 10 € - 15 € = -5 €
- If the buyer has not exercised the option:
  Seller's profit: 0 €
  Buyer's profit: 0 €

If the seller has invested 8 €:

- If the buyer has exercised the option:
  Seller's profit: 15 € - 8 € = 7 €
  Buyer's profit: 22 € - 15 € = 7 €
- If the buyer has not exercised the option:
  Seller's profit: -8 €
  Buyer's profit: 0 €

The following instructions were handed out to the participants in the OCR treatment:

<u>Experimental Instructions</u>

In this experiment there is always one seller who interacts with one buyer. You are randomly assigned either to the role of the seller or to the role of the buyer.

The experiment consists of only one single period.
The period consists of up to five stages.

Stage 1:
On the screen you can see whether you have been assigned to the role of the seller or to the role of the buyer.

Both the seller and the buyer can decide whether or not they agree to the following contract:

„The buyer has the option to purchase a particular good at the price of 15 € in stage 3."

If one or both parties do not agree to the contract, the experiment is over. Then each party makes a profit of 0 €.

If both parties agree to the contract, then stage 2 follows.

Stage 2:
The seller can make an investment decision. He can invest either 0 € or 8 € and thereby he can influence the buyer's valuation for the good.

If the seller has invested 0 €, then the buyer's valuation for the good is 10 €.
If the seller has invested 8 €, then the buyer's valuation for the good is 22 €.

Stage 3:
The buyer learns the seller's investment decision and so now he knows his valuation. Then the buyer can exercise the option.

- If the buyer has exercised the option, the experiment is over and the profits are as follows:

  If the seller has invested 0 €:
  Seller's profit: 15 € - 0 € = 15 €
  Buyer's profit: 10 € - 15 € = -5 €

  If the seller has invested 8 €:
  Seller's profit: 15 € - 8 € = 7 €
  Buyer's profit: 22 € - 15 € = 7 €

- If the buyer has not exercised the option, then stage 4 follows.

Stage 4:
Now the buyer can make an ultimate price offer p to the seller at which the buyer is willing to buy the good. (The price has to be an integer between zero and the buyer's valuation for the good.)

Stage 5:
The seller can decide whether he wants to sell the good to the buyer at the offered price p.

At the end of stage 5, the profits are as follows.

If the seller has invested 0 €:

- If the seller has accepted the offer:
  Seller's profit: p € - 0 € = p €
  Buyer's profit: 10 € - p €
- If the seller has not accepted the offer:
  Seller's profit: 0 €
  Buyer's profit: 0 €

If the seller has invested 8 €:

- If the seller has accepted the offer:
  Seller's profit: p € - 8 €
  Buyer's profit: 22 € - p €
- If the seller has not accepted the offer:
  Seller's profit: -8 €
  Buyer's profit: 0 €

Furthermore, at the end of each of the four different instructions, the following information was provided:

Your payoff:
In addition to the (possibly negative) profit realized in the experiment you get 8 € and the resulting amount is paid out to you in cash.

Please note:
During the whole experiment communication is not allowed. If you have a question, please raise your hand out of the cabin. All decisions are anonymous; i.e., no participant ever learns the identity of a person who has made a particular decision. The payment is conducted anonymously, too; i.e., no participant learns what the payoff of another participant is.