

An experimental comparison of reliance levels under alternative breach remedies

Randolph Sloof*

Edwin Leuven*

Hessel Oosterbeek *

Joep Sonnemans**

Abstract

Breach remedies serve an important role in protecting relationship-specific investments. Theory predicts that some common remedies protect too well and induce overinvestment because of complete insurance against potential separation, and the possibility to prevent breach by increasing the damage payment due through the investment made. In this paper we report on an experiment designed to address whether these two motives show up in practice. In line with theoretical predictions we find that overinvestment does not occur under liquidated damages. In case of expectation damages the full insurance motive indeed appears to be operative. In case of reliance damages both motives are at work, as is predicted.

* University of Amsterdam, NWO Priority Program ‘Scholar’, and Tinbergen Institute; sloof@fee.uva.nl, leuven@fee.uva.nl, hessel@fee.uva.nl.

** University of Amsterdam, CREED and Tinbergen Institute; joepe@fee.uva.nl.

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1 Introduction

Through their provision of commitment, breach remedies play an important role in protecting (non-contractable) relationship-specific investments.¹ Without contractual commitment, under-investment may occur because of holdup (cf. Williamson, 1985). Breach remedies can be used to overcome this holdup problem, because they protect the investor against appropriation of the return on the investment by the trading partner. The following three breach remedies are commonly used in practice and received considerable attention in the theoretical literature (cf. Cooter and Ulen, 1997; Edlin, 1997; Posner, 1977):

- liquidated damages: the breacher has to pay a fixed amount – specified in the initial contract – to the victim of breach;
- expectation damages: the breacher has to pay the amount that makes the victim equally well off as under contract performance;
- reliance damages: the breacher compensates the victim such that the latter is equally well off as before the contract had been signed.

Liquidated damages are always privately stipulated and have to be incorporated explicitly into the initial contract. The other two remedies are, in various situations and circumstances, incorporated in the common law as being the default remedy.

The theoretical literature reveals that breach remedies generally lead to too much protection thereby inducing overinvestment.² There are generally two motives to overinvest in the presence of breach remedies. First, under expectation damages and reliance damages, the breach remedy effectively insures the investor completely against potential separation. When separation (no trade between the original contract partners) is efficient in some possible contingencies, the investor is then over-insured from a social point of view. She

¹Within the Law and Economics literature, specific investments are usually referred to as reliance expenditures. In this paper we use the terms investment and reliance interchangeably.

²Under certain ingeniously designed contracts breach remedies do not necessarily induce overinvestment. In particular, Edlin and Reichelstein (1996) show that an initial contract that specifies a suitably chosen intermediate amount of trade together with a breach remedy secures efficient investments. In practice, however, such elaborate contracts may not be used. Moreover, they may also be unavailable because they require the contract to be “divisible”. In this paper we focus on the discrete framework in which contracts are “entire” ($q \in \{0, 1\}$).

will not accurately take account of the fact that the investment is not always socially profitable, and she will therefore overinvest. The second motive to overinvest is only operative under the reliance damages rule. Because the investor is in that case better off when the parties trade according to the contract than when they separate, she may have an incentive to reduce the probability of separation by investing more. Higher investments lead to a larger damage payment in case of a breach, making breach less attractive for the other party.

This paper reports about an experiment designed to test the above predictions concerning overinvestment under the various breach remedies.³ We do this in an environment in which renegotiation of the initial contract is not possible (as in Shavell, 1980, and in Chung, 1992). This does not imply that we consider the no-renegotiation setup to be more realistic or relevant than a setup in which renegotiation is possible. It is even the case that holdup is predicted not to occur in the absence of renegotiation. The reason for excluding a renegotiation stage is that the two overinvestment motives are also predicted to be at work in the no-renegotiation case (cf. Shavell, 1980), meaning that this stage is not crucial for what we want to establish in this paper. At the same time, excluding a renegotiation stage keeps the experiment as simple and clear-cut as possible. This is important for two reasons. First, it minimizes the potential for subjects to be confused or to misunderstand the experiment. Second, adding an extra stage changes the structure and the nature of the relationship. While the game theoretical predictions remain essentially the same, there are more possibilities to deviate which makes interpretation of deviating behavior more ambiguous.

The remainder of this paper is organized as follows. Section 2 describes the basic setup of the three stage game studied experimentally and derives equilibrium predictions for each of the three breach remedies. Section 3 describes the experimental design and formulates the hypotheses that are put to the test. The experimental results are presented in Section 4. Observed behavior is by and large in line with the theoretical predictions. There is, however, one instance in which a substantial fraction of the subjects deviate systematically from predicted behavior. Section 5 discusses possible explanations for this. The final section

³The theoretical literature also considers the remedy of "specific performance", which prohibits breach of contract by requiring an agent to adhere to the contract if the other party asks him to do so. We do not study this remedy experimentally since breach is not possible. The experiment then reduces to a single agent decision (investment) problem under certainty, lacking any strategic interaction.

summarizes and concludes.

2 The model

2.1 Basic setup of the model

We consider a bilateral trade relationship between a female buyer and a male seller. Both parties are assumed to be risk-neutral. The buyer can make an upfront investment and the seller has an alternative trading opportunity outside the relationship.⁴ Trade between the buyer and the seller is restricted to one unit. The seller's production costs are assumed to be fixed and are normalized at zero. When the buyer and the seller trade, gross surplus equals $R(I) = V + v \cdot I$. Here $I \in [0, v]$ denotes the investment made by the buyer. This investment is completely relationship-specific and also non-contractable, so that without some arrangement that protects the investment holdup may occur. Parameter $V > 0$ represents the buyer's basic valuation when trading with the seller, and $v > 0$ is the constant increment in the buyer's valuation with each unit of investment. The costs of investment equal $C(I) = I^2$.

Besides trading with the buyer, the seller may also trade his single unit outside the relationship at a fixed price. Since the investment is completely relationship-specific, this outside bid b does not depend on the investment made by the buyer. The outside bid b is unknown at the time the buyer decides on her investment. In our simple setup b can either be low (b_l) or high (b_h). The probability that the latter case applies equals p . The buyer has no alternative opportunity. The timing of events is shown in Figure 1 (cf. Che and Chung, 1999).

The standard holdup game starts with the buyer and the seller negotiating and signing a contract that governs their relationship. This initial contract specifies that the seller receives a fixed payment f in case they trade according to the original contract. After the initial contract has been signed, the buyer chooses

⁴This assumption is without loss of generality. We could as well assume that the seller makes the investment and the buyer has the outside trading opportunity (cf. Rogerson, 1984; Shavell, 1980). A real world example that fits the setup used in the main text concerns a relationship between an employer and a worker, in which the employer invests in firm specific human capital and the worker has the opportunity to work for another (outside) employer at a fixed wage (cf. MacLeod and Malcomson, 1993, Malcomson, 1997). Rather than the exact role of the investor (either buyer or seller), the important assumption in our setup is that the investor has no outside opportunity. The investor therefore never has an incentive to breach the original contract.

the level of investment. Then uncertainty about b is resolved and its value becomes known to both players. Knowing the price he can get from the alternative buyer, the seller decides whether to breach the original contract or not. In case of breach he has to pay damages of $\delta(I)$ to the buyer. This payment schedule may be agreed upon by both parties and incorporated into the initial contract (privately stipulated damages) or may be the default remedy. In the last stage the buyer and the seller may renegotiate the outcome that pertains after the seller's breach decision. For instance, they may mutually agree on lowering the damage payment $\delta(I)$ in order to induce an efficient separation. After these renegotiations the final trade decision determines the players' payoffs.

We consider a condensed form of this game. We omit stage 0 in which the buyer and the seller negotiate the initial pre-investment contract. We simply assume that such an initial contract specifying f already exists. Moreover, we do not allow for renegotiation after the seller's breach decision. While this final stage is crucial for holdup to occur, the predictions with regard to overinvestment do not depend on the inclusion of this stage (cf. Shavell, 1980). Since overinvestment motives are the focus of this paper we omit this final stage, as this gives the cleanest test of the working of these motives. Including a renegotiation stage may lead to the introduction of other interfering factors.

The remaining three-stage game consists of the buyer's investment decision in stage 1, nature's outside bid draw in stage 2, and the seller's breach decision at stage 3. In Figure 1 these three stages are bold faced.

The breach remedies studied in this paper all imply a different damage schedule $\delta(I)$.

- Liquidated damages (LI): $\delta_{LI}(I) \equiv \delta_{LI} \geq 0$. A *fixed* amount, specified in the initial contract, has to be paid by the seller in case of a breach;
- Expectation damages (EX): $\delta_{EX}(I) \equiv V + v \cdot I - f$. The seller compensates the buyer such that the latter is equally well off as under contract performance. That is, the seller pays the buyer her *expectancy*, i.e. the expected gross gains from trade;
- Reliance damages (RE): $\delta_{RE}(I) = I^2$. The seller compensates the buyer such that she is equally well off as before the trade agreement had been signed. That is, the seller pays back the buyer's *investment costs*.

The theoretical literature focuses on the investment and breach (in)efficiencies that the various remedies induce. The socially efficient level of investment I^* follows from maximizing expected net social surplus $S(I)$. Due to our assumption that $b_l < V$,⁵ trade between the buyer and the seller is always efficient when the outside bid turns out to be low, irrespective of the level of investment chosen. Given this assumption, I^* follows from:

$$\max_I S(I) = (1 - p)(V + v \cdot I) + p \cdot \max\{V + v \cdot I, b_h\} - I^2$$

The solution to the above maximization problem is given by $I^* = \frac{1}{2}v$ when $b_h \leq V + \frac{1}{4}(2 - p)v^2$, and $I^* = \frac{1}{2}(1 - p)v$ when $b_h \geq V + \frac{1}{4}(2 - p)v^2$.⁶ In the first case where b_h is rather low it holds that, at the efficient investment level, trade between the buyer and the seller is always efficient, i.e. for both $b = b_l$ and $b = b_h$. In the second case where b_h is rather high it holds for I^* that separation, and thus breach, is efficient when $b = b_h$. In the latter case an investor who wants to choose the efficient level has to take into account that this investment pays off only when $b = b_l$. We take this latter case as being both the more plausible and the more interesting one. Throughout we assume that:

Assumption 1. $b_h > V + \frac{1}{4}(2 - p)v^2$

Under assumption 1 it holds that, at the efficient investment level, trade is efficient when $b = b_l$, and that separation is efficient in case $b = b_h$. We then have that $I^* = \frac{1}{2}(1 - p)v$ and that $S(I^*) = (1 - p)V + p \cdot b_h + \frac{1}{4}(1 - p)^2v^2$. Both I^* and $S(I^*)$ can be used as normative benchmarks to assess the performance of the various breach remedies.

2.2 Equilibrium breach behavior

In this and the following subsection we solve for the equilibria of the three stage game described above. The equilibrium concept employed is subgame perfect Nash equilibrium. We first determine equilibrium breach behavior under each of the three breach remedies. In the next subsection we determine the corresponding

⁵We assume $f \in (b_l, V)$ to secure that both the buyer and the seller obtain a payoff under contract performance that is at least as large as what they would get in the absence of a contract.

⁶Details are given in the appendix.

equilibrium levels of investment.

The breach decision of the seller is a simple dichotomous choice. When he does not breach the seller obtains the fixed payment f . In case of breach he sells his single unit to the outside buyer at a price b , but also has to pay the original buyer $\delta(I)$ in damages. The seller thus chooses to breach iff $b > f + \delta(I)$.⁷ Following Shavell (1980), we let $B(\delta(I)) = \{b | b > f + \delta(I)\} \subseteq \{b_l, b_h\}$ denote the breach set, i.e. the set of outside bid values for which the seller prefers to breach rather than to perform the contract. Due to our assumption that $b_l < f < V$ we actually have $B(\delta(I)) \subseteq \{b_h\}$. Clearly, the breach set depends on the specification of $\delta(I)$.

By substituting the various formulas for $\delta(I)$ the breach set under the different breach remedies can be obtained. For a *given* level of investment we have in our setup that

$$\emptyset = B_{LI}(\delta_{LI} > b_h - f) \subseteq B_{EX}(I) = B^*(I) \subseteq B_{RE}(I) \subseteq B_{LI}(\delta_{LI} < b_h - f) = \{b_h\}$$

Here $B_{LI}(\delta_{LI} > b_h - f)$ and $B_{LI}(\delta_{LI} < b_h - f)$ are used to denote the breach sets under liquidated damages for the cases where $\delta_{LI} > b_h - f$ and $\delta_{LI} < b_h - f$, respectively. Note that the breach set under liquidated damages is independent of the level of investment chosen. $B^*(I)$ denotes the set of outside bid values for which breach is socially efficient. We thus in general observe that under high liquidated damages ($\delta_{LI} > b_h - f$) too few breaches occur from a social point of view. For instance, when $b = b_h$ and $b_h > V + v \cdot I$ the buyer and the seller inefficiently stick together; breach is then efficient. High liquidated damages $\delta_{LI} > b_h - f$ make breach prohibitively costly. Contrarily, under reliance damages and low liquidated damages ($\delta_{LI} < b_h - f$) the seller generally breaches (weakly) too often. The expectation damages rule is the only one that induces efficient separations for any given level of investment chosen.

Notice that $B_{EX}(I) \subseteq B_{RE}(I)$ holds for a *given* level of investment. That is, only for a given level of investment the seller is more inclined to breach under reliance damages than under expectation damages. But, as the equilibrium investment level under reliance damages (weakly) exceeds the one under expectation damages (cf. Shavell, 1980), it may occur that under the respective *equilibrium* levels of investment,

⁷We resolve any indifference in favor of selling to the incumbent buyer. This tie-breaking assumption is inessential for our results.

breach occurs less often under reliance damages than under expectation damages: $B_{RE}(I_{RE}^*) \subseteq B_{EX}(I_{EX}^*)$ (where I_{RE}^* and I_{EX}^* denote the equilibrium investment levels under the respective breach schedules). The next subsection reveals that this may indeed occur in our setup.

2.3 Equilibrium investment behavior

Anticipating the breach decision of the seller, the buyer chooses the investment level that maximizes her expected payoffs. Table 1 summarizes the predicted investment levels.⁸

From Table 1 it follows that breach remedies typically lead to overinvestment in relation-specific capital. Only low liquidated damages ($\delta_{LI} < b_h - f$) induce efficient investments. In our setup the optimal liquidated damage schedule is not unique, as any $\delta_{LI} < b_h - f$ will work. In the other cases overinvestment is induced by two motives.

The first one – the *full insurance* motive – follows from the fact that the buyer is completely protected against a potential breach. Under high liquidated damages ($\delta_{LI} > b_h - f$) this trivially follows from breach being prohibitively costly to the seller, such that it never occurs. In the case of EX this follows because the buyer is completely insured against potential separation. Irrespective of the breach decision of the seller, the buyer always obtains her expectancy. She therefore just sees reliance as an investment with a certain payoff. Under the RE breach remedy the buyer always recovers at least her investment costs. This effectively insures her against the risk that the investment may appear (socially) unprofitable after all. Recall that Assumption 1 was made such that an investor who wants to invest the social optimum has to take into account that separation is efficient when $b = b_h$ and that, from a social point of view, the investment therefore only pays off when $b = b_l$. This is reflected in the fact that the probability $(1 - p)$ that $b = b_l$ appears in the expression for I^* : $I^* = \frac{1}{2}(1 - p)v$. When the investor is fully insured her investment is independent of $(1 - p)$ and equals $\frac{1}{2}v$. Full insurance thus constitutes over-insurance from a social point of view and leads to overinvestment.

The second motive to overinvest is only present under reliance damages. This motive will be referred to as the *breach prevention* motive. Because the buyer is worse off under breach compared to no-breach, she

⁸A formal derivation can be found in the appendix to this paper.

has an incentive to effectively reduce the probability of breach through higher investments (Chung, 1995). Higher investments increase the damage payment $\delta_{RE}(I)$ the seller has to pay when he breaches, and therefore make breach less attractive and likely. This second motive to overinvest aggravates the overinvestment problem due to the full insurance motive. In Table 1 the breach prevention motive is only effective in the second case of RE that applies when p is relatively high. There the buyer overinvests even relative to the level $I = \frac{1}{2}v$ which she would have chosen when only the full insurance motive is present.

In the experiment we examine both the full insurance and the breach prevention motives to overinvest. This is done in two complementary ways. For each of the breach remedies considered, we test the comparative statics predictions concerning the level of investment chosen with respect to p (cf. Table 1). We also compare the observed investment levels across the three different breach remedies.

3 Experimental design and hypotheses

This section consists of three parts. The first subsection discusses the choice of parameter values used in the experiment. The next subsection summarizes the hypotheses obtained from the game-theoretical predictions. The final subsection gives an overview of the experimental treatments and sessions.

3.1 Choice of parameters

To convert the model of Section 2 into an experiment we have to choose specific values for the basic parameters v , V , f , b_l , b_h , and p . Because we want to test the comparative statics predictions with respect to p , two values for p have been chosen. These are referred to as p_1 and p_2 . Our choices are led by the following considerations. First, recall that v by assumption equals both the largest possible level of investment and the marginal increment in valuation with each unit of investment. Because our main focus is on investment behavior, we allowed for enough variation in investment levels. We therefore chose $v=100$ and restricted the possible investment levels to multiples of 5. Effectively, 21 different investment levels were thus allowed for, viz. $\{0, 5, \dots, 100\}$.⁹ Second, equilibrium predictions remain exactly the same when we add a positive

⁹We did not allow for every integer value between 0 and 100 for the following two reasons. First, by restricting investment levels to multiples of five, different investment levels lead to non-trivial differences in final payoffs. This strengthens subjects' (relative)

constant to the ‘level’ parameters V , f , b_l , b_h . Because we have $b_l < f < V < b_h$ by assumption, we normalized b_l to zero.¹⁰ Third, the probabilities p_1 and p_2 were chosen such that they would not be considered negligible by the subjects, and that the potential equilibrium investment levels $\frac{1}{2}v$, $\frac{1}{2}(1 - p_1)v$ and $\frac{1}{2}(1 - p_2)v$ were sufficiently far apart (but not too close to 0). $p_1 = \frac{1}{5}$ and $p_2 = \frac{3}{5}$ satisfy these requirements.

We determined V , f and b_h in the following way. First, we needed to have $b_h > V + 4500$, to satisfy Assumption 1. Second, we chose them such that under reliance damages the first case in Table 1 applies when $p = p_1$ and the second case when $p = p_2$. The equilibrium investment level is then indeed increasing in p under RE, yielding the comparative statics prediction we want to test. Third, for the case where $p = p_2$ we wanted $I_{RE} = \sqrt{b_h - f}$ to be an integer and an intuitive number, such that it was easily seen which minimum level of investment would (theoretically) prevent breach. Because Assumption 1 requires $I_{RE} \geq 67.08$ in this case and the comparative statics prediction with respect to p does not hold for $I_{RE} = 70$, we chose $I_{RE} = 80$. Thus, $b_h = f + 6,400$. Our choices of $f=600$ and $V=1000$, then secured that all requirements are met.

Finally, for the case of liquidated damages the value of the fixed amount δ_{LI} also had to be determined. Here we chose $\delta_{LI}=3400$. This value equals the mean of the efficient expectation damages values ($\delta_{LI} = \delta_{EX}(I^*)$) under $p = p_1$ (4,400) and $p = p_2$ (2,400) respectively.¹¹ We chose the mean because equilibrium predictions for $\delta_{LI} = 2,400$ and $\delta_{LI} = 4,400$ (and thus also the mean) are exactly the same, and we did not want to change anything else besides p when we considered the effect of changes in p . Given all the above choices for the parameters, the net payoff tables that result under the three different breach remedies are given in the Appendix.¹²

incentives to choose a particular investment level. Second, the experiment was easier to explain to the subjects. In particular, we presented all 21 net payoff tables, one for each possible investment level, on one single sheet (see the Web Appendix). Clearly we could not have done so with 101 different investment levels.

¹⁰Under our assumption that $b_l < f < V < b_h$ actually a positive constant can be added to only f , V and b_h (leaving b_l intact) without affecting equilibrium predictions.

¹¹Efficient expectation damages in general constitute the optimal private damage schedule in a variety of settings (cf. Spier and Whinston, 1995).

¹²These net payoff tables are shown in the same way as they were presented to the subjects. In this presentation player A corresponds to the buyer and player B to the seller. The columns under Blue correspond to the payoffs after $b = b_l = 0$, the columns under Yellow to the net payoffs after $b = b_h = 7,000$. In the experiment we used T rather than I to denote the investment. Lastly, X corresponds to no-breach, and Y corresponds to breach.

3.2 Hypotheses

Equilibrium predictions based on subgame perfection are summarized in Table 2.¹³ These predictions lead to the following hypotheses:

1. Under LI the investment levels observed are *decreasing* in p ; under EX the investment levels observed are *independent* of p ; under RE the investment levels observed are *increasing* in p ;
2. Investment levels are *higher* under EX and RE than under LI; investment levels are *higher* under RE-High than under EX-High;¹⁴
3. The seller's breach decision is always based on own payoff maximization;
4. The Pareto ranking of the three breach remedies equals $LI > EX > RE$.

Hypothesis 1 is based on the within remedy comparative statics predictions. The predicted comparative statics in p provide a method to test the presence of the two motives to overinvest. When the observed investment level is decreasing in p neither the full insurance nor the breach prevention motive appears to be effective. This is the situation predicted for the liquidated damages measure. Under LI the buyer only obtains a return on her investment when $b = b_l$ and the seller does not breach. She thus realizes that her investment does not always pay off. When the probability p that this latter situation applies increases, she will invest less. When the observed investment level is independent of p , (only) the full insurance motive appears to be operative. This is the situation predicted for expectation damages. Under EX the buyer is completely insured against potential breach because she always obtains her expectancy, and her investment is therefore predicted to be independent of p . In case the observed investment level is increasing in p , both the full insurance and the breach prevention motive appear to exist. This situation theoretically only applies for the reliance damages case. Because the buyer always recovers at least her investment costs under RE,

¹³The equilibrium predictions presented in Table 1 of Section 2.3 refer to the model with continuous action spaces. Clearly, the number of possible investment levels is necessarily finite in an experiment. As a result, the equilibrium investment level may not always be unique. The discrete model used in our experiment allows for two subgame perfect equilibria when $p = \frac{3}{5}$ and the RE remedy applies: $I_{RE} = 80$ and $I_{RE} = 85$. The first equilibrium level requires that the seller chooses to breach after $b = b_h$ with a probability below $\frac{13}{80}$. In all other cases the equilibrium investment level is unique.

¹⁴"High" in RE-High and EX-High refers to the case where $p = p_2 = \frac{3}{5}$.

she is effectively fully insured against potential breach. But, she gets a positive payoff only when the seller does not breach. When breach is rather likely to occur (p is high such that RE-High applies), the buyer is more inclined to prevent breach by increasing the damage payment $\delta(I)$ through higher investments.

Hypothesis 2 is based on the the between remedy comparative statics predictions. These provide a complementary way to establish whether the two motives to overinvest are present. The third hypothesis conjectures that the seller will always make his breach decision solely on the basis of his own payoffs. The final hypothesis translates the equilibrium predictions concerning investment and breach behavior into a prediction about efficiency losses. These are predicted to be smallest (even absent) under LI and largest under RE. The prediction that EX performs *strictly* better on efficiency grounds than RE follows from our consideration of a non-optimal contract in the RE-High case. For optimal contracts EX only performs *weakly* better than RE.

3.3 Treatments and sessions

The experiment is based on a 3×2 design. We consider three breach remedies and two values of p . In each session only one remedy was considered. All subjects within a session were confronted with both values of p . We ran three sessions per remedy, such that we had nine sessions in total. Overall 180 subjects participated in the experiment, with 20 participants per session. The subject pool consisted of the undergraduate student population of the University of Amsterdam. Somewhat over 50 % of the subjects were students in economics. They earned on average 44 Dutch guilders (approximately US\$ 20) in about one and a half hours.

Each session contained 32 rounds. In each round the three-stage game of Figure 1 was played. The 32 rounds were divided into four blocks of eight rounds. In the first two sessions of each remedy the first (rounds 1 through 8) and third block (rounds 17 through 24) considered p equal to $\frac{1}{5}$, in the other two blocks p was equal to $\frac{3}{5}$. In the third session of each remedy, this ordering was reversed so that we could test for the presence of ordering effects. The main reason to employ this particular block structure was that it allows us to test whether any learning effects are present in the data, by comparing subjects' behavior in block one

(two) with their behavior in block three (four). The start of every new block and the change of p were both verbally announced and shown on the computer screen.

Subjects' roles varied over the rounds. This enhances subjects' awareness of the other player's decision problem. Alternating roles provide subjects with an opportunity to see things from the other player's viewpoint and thus understand the game better. It also doubles the number of investors observed in the experiment. Within each block of eight rounds each subject was assigned the role of buyer exactly four times, and the role of seller also four times. In each single round subjects were anonymously paired and could meet each other only once within each block of eight rounds. Subjects were explicitly informed about the matching procedure. What the subjects did not know was that within each session they were divided into two separate groups of 10 subjects. Matching of pairs only took place within this group. We did this in order to generate two independent aggregate observations per session.

In order to enhance comparability the empirical distribution of the outside bid b was exactly the same over the different groups and sessions. We used an empirical distribution that in the aggregate exactly matches the theoretical distribution, but contains sufficient variation over the individual subjects. Another common element to all sessions was that we provided subjects with an initial endowment. Each subject received 6,000 experimental points at the start of the experiment. The conversion rate was 1 guilder for 1,500 points, so that 1 US dollar corresponded to about 3,300 points. We provided subjects with an initial endowment because we wanted buyers to have already some amount to spend when they had to take their first investment decision. Otherwise they may have felt somewhat reluctant to invest in order to avoid an immediate debt.

The equilibrium point predictions appearing in Table 2 only hold under the assumption of risk neutrality. When subjects are risk-averse, these point predictions may change.¹⁵ It must be noted, though, that the comparative statics hypotheses continue to apply, even in the presence of risk averse subjects. This also holds for the predictions based on the comparison of investment levels across different breach remedies.

¹⁵Under EX the buyer effectively faces no uncertainty at all, so for that case predictions remain exactly the same for any risk attitude of the buyer and the seller. This does not apply to the two other breach remedies. Also the theoretical Pareto-ranking of the different damage rules may change under alternative risk attitudes, because the various rules lead to different allocations of risk (cf. Shavell, 1984; Mahoney, 1995).

The assumption of risk neutrality thus does not influence our main hypotheses. We therefore chose not to use a lottery-ticket payoff procedure in order to induce risk-neutrality, also because previous experiments indicated that this procedure may be ineffective (cf. Cooper et al., 1990; Millner and Pratt, 1991; Walker, Smith, and Cox, 1990).

The experiment was computerized. Subjects started with on-screen instructions. All subjects had to answer some questions correctly before the experiment started. For example, they had to calculate the earnings of subjects for some hypothetical – not necessarily realistic – situations. Subjects also received a summary of the instructions on paper (see the appendix). The instructions and the experiment were phrased as neutrally as possible; words like opponent, game, player, buyer or seller were avoided. Subjects received on paper a table which 21 payoff matrices for all feasible investment levels. At the end of the experiment subjects filled out a short questionnaire and the earned experimental points were exchanged for money. Subjects were paid individually and discreetly.

4 Experimental results

This section presents the findings of our experiment in the form of five Results. The presentation is divided into three subsections which deal respectively with investment levels, breach decisions and efficiency.

4.1 Investment levels

The first result concerns the comparative statics regarding the relation between investment levels and the probability of a high outside bid (cf. Hypothesis 1).

Result 1. Under LI investment levels decrease when p increases. Under EX investment levels remain virtually constant when p changes. Under RE investment levels increase when p increases.

Evidence supporting Result 1 is provided in Table 3. This table reports both the mean investment levels and standard deviations by treatment and also gives test statistics for equality of investment levels across

treatments.¹⁶ For each subject we calculated the mean investment level separately for $p = \frac{1}{5}$ and for $p = \frac{3}{5}$. For each breach remedy we can then test for the equality of these individual mean investment levels using Wilcoxon signrank tests. For LI and EX it is found that the mean investment levels decrease when the probability of a high outside bid increases from $\frac{1}{5}$ to $\frac{3}{5}$, while for RE an increase in the individual mean investment levels is observed.

Similar conclusions are obtained from the group level data. Recall that we divided the 20 subjects within a session into two groups that were independently matched. Members of one group were never matched with a member of the other group. We thus have for each remedy six independent observations at the aggregate group level. Under both LI and EX all groups invest less in the Low treatment than in the High treatment. For all six groups that were confronted with the RE breach remedy we observe the opposite. Investment levels are higher in the RE-High treatment. The figures in italics in Table 3 are the test statistics based on group level observations.

The observed comparative statics under LI and RE are in line with equilibrium predictions. Those for EX are not. Subgame perfection namely predicts that the investment level does *not* change when the level of p changes. But, although the fall of the mean investment level in the EX-treatment is statistically significant, it is small in absolute magnitude (only 6%). Hence, we interpret the findings in Table 3 as supportive for the equilibrium predictions set out in Section 3.2.

The next result relates to a comparison of investment levels across different breach remedies (cf. Hypothesis 2).

Result 2. Investment levels are significantly higher under EX and RE than under LI, and significantly higher under RE-High than under EX-High.

Evidence for Result 2 is again provided in Table 3. In all cases the realized average investment level

¹⁶Using Mann-Whitney ranksum tests, we found no differences at the 10 % level in investment levels between the three sessions that were held for each of the three breach remedy treatments. These tests are based on the mean investment levels per level of p for each subject. This implies that the difference in ordering of the level of p between the first two and the last session per treatment makes no difference. Therefore we report results based on pooled sessions. Furthermore, using Wilcoxon signrank tests we did not find any statistical differences at the 10 % level between rounds 1-8 and rounds 17-24, and between rounds 9-16 and rounds 25-32. The latter results indicate that no significant learning effects can be detected in the data.

is within (a fraction of) a standard deviation of the predicted investment level. This implies that we cannot reject that the mean actual investment levels are equal to the predicted ones. The deviation is largest under reliance damages when the probability of a high outside bid equals $\frac{3}{5}$. Here the average investment level is 75 while 80/85 is predicted. These observations imply that the average investment levels under LI are almost equal to the socially efficient levels of 40 and 20, while under the other two damage schedules average investment levels as predicted exceed the first best levels.

Results from Mann-Whitney ranksum tests confirm that investment levels are significantly higher under EX and RE than under LI, and also significantly higher under RE-High than under EX-High. Again tests are performed at the level of individuals' mean investment levels and on group level data. Comparing any two remedies we reject equality of distributions well below the 5 % level.

Together Results 1 and 2 provide strong evidence that both motives for overinvestment are at work. First, the operation of the full insurance motive is supported by the difference between the comparative statics results for EX and LI observed in Result 1, and by the across remedies comparison between EX (and RE) and LI reported in Result 2. Second, both the difference between the comparative statics results for RE and EX (Result 1) and the significant difference between observed investment levels under RE-High and EX-High (Result 2) point at the presence of the breach prevention motive. Our experimental results thus confirm the distortionary impact of breach remedies on the incentives to invest.

Although the breach prevention motive is clearly operative under reliance damages, the finding that in the RE-High treatment the mean investment level falls short of the equilibrium levels of 80 and 85 indicates that it causes less overinvestment than predicted. The next result provides details.

Result 3. Under the RE-High treatment the distribution of investment levels is bi-modal with peaks at the predicted level of 80/85 and at 50.

Table 3 presents means and standard deviations. More detailed information concerning separate investment decisions is given in Figure 2 which depicts the distributions of investment levels by treatment.¹⁷ From these distributions it is apparent that the mean levels in Table 3 disguise quite some dispersion. In the LI

¹⁷Here separate investment decisions rather than individuals' means investment levels are the units of observation.

treatments actual investment levels cluster around the predicted levels of 40 (for LI-Low) and 20 (for LI-High), with values in a -10 to +10 neighborhood occurring frequently. In the LI-Low treatment the mode is 50 rather than 40, but this is compensated for by choices of 30. In the EX treatments a vast majority of actual investment decisions equals the predicted value of 50. In the EX-High treatment it occurs somewhat more often that subjects choose investment levels a bit below 50. The RE-Low treatment shows the least variation in investment levels, with almost 90 % of the investment decisions equal to 50.¹⁸ RE-High is the only treatment with a clear bi-modal distribution of investment levels. Besides a peak at the investment levels of 85 and 80 there is a second peak at 50.¹⁹ Levels of 50 rather than 80/85 imply a substantially smaller overinvestment than predicted. In section 5 we consider possible explanations for this observation.

4.2 Breach decisions

The next result relates to actually observed breach decisions.

Result 4. Sellers' breach decisions are almost always (1) in line with own payoff maximization, and (2) socially efficient.

Table 4 tabulates for each breach remedy the breach decisions against an index indicating whether the seller gains from breaching ($b > f + \delta(I)$) or loses from doing so ($b < f + \delta(I)$). Also a third case is distinguished in which the seller's payoff is independent of his breach decision ($b = f + \delta(I)$). Actual breach decisions almost always coincide with equilibrium predictions. Of the 2,880 breach decisions less than 2 % (40 decisions) contradict with own payoff maximization. Moreover, the breach decision is typically also socially efficient. In less than 3 % of the cases inefficient trades with either the original or the outside buyer occur (see the numbers in parentheses in Table 4). Inefficient breach decisions mostly occur under reliance damages. There sellers in the aggregate indeed show a tendency of breaching too often from a social point of view. Of the 214 breaches observed under RE about 26 % are inefficient. This particularly

¹⁸There is a small other peak in the distribution near 80-85 (4.8 %). In the RE-Low treatment there is no rationale for these particular investment levels. Probably it occurs sometimes that subjects think that they are playing the RE-High instead of the RE-Low treatment (although we explicitly tried to avoid this by announcing the change in p -regime also verbally, in addition to the announcement on the computer screen).

¹⁹The frequencies belonging to these investment levels are respectively 54 %, 19 % and 18 %.

happens when buyers invested 80 or more. In the first column there are 14 observations where sellers breach while this is costly to themselves as well as to the buyer. In the middle column there are 33 cases in which breaching is costless to the seller but harmful to the buyer. This may be attributed to sellers wanting to punish buyers for their overinvestment. Recall that investment levels of 80 or 85 intend to prevent the seller from breaching when he gets a high outside bid.

4.3 Efficiency

Our final result relates to the realized efficiency of the different breach remedies.

Result 5. The ranking of the remedies in terms of attained efficiency levels is: LI>EX>RE. Efficiency is higher when the probability of a high outside bid is low.

This result is supported by the findings reported in Table 5. Column (1) gives the expected value of the joint payoffs of the seller and the buyer when investment levels and breach decisions are equal to the subgame perfect predictions. The predicted expected joint payoffs under LI equal the largest possible expected payoffs $S(I^*)$, because equilibrium behavior under LI corresponds with socially efficient behavior. The second column contains the average value of the actual joint payoffs. By subtracting the entries in column (2) from $S(I^*)$ the overall observed inefficiencies are obtained. Columns (3) to (5) decompose overall inefficiency into three different sources. The first type of inefficiency is due to inefficient investments.²⁰ Column (4) depicts the average loss in joint payoffs that can be attributed to inefficient breach decisions.²¹ The third source of inefficiency is due to the fact that the empirical distribution of b conditional on the investment level chosen may differ (slightly) from the theoretical distribution.²² The resulting (in)efficiency cannot be attributed to the decisions of individual subjects and is therefore referred to as residual. The last

²⁰This inefficiency is obtained from calculating $S(I^*) - S(I_{chosen})$ for each interaction and subsequently averaging out over all 480 observations within a treatment.

²¹For each interaction the difference in joint payoffs under the efficient and the actual breach decision is calculated, taking the actual investment level chosen as given. The reported breach inefficiencies reflect the average difference within a treatment.

²²Our experimental procedures ensured that the realized frequencies of high outside bids exactly equaled 20 % and 60 % in the Low and High treatments respectively. That is, we controlled the unconditional empirical distribution of b . We did not control the empirical distribution of b conditional on the value of I , such that also this conditional distribution exactly equaled the theoretical distribution.

two columns present fractions between predicted expected joint payoffs, actual joint payoffs and maximal expected joint payoffs $S(I^*)$.

Although the average investment levels in the LI treatments are close to the efficient investment levels, average realized payoffs are somewhat below the predicted expected payoffs. This is caused by the fact that each deviation from the efficient investment level results in an efficiency loss. While over- and underinvestments cancel out and make the average investment level close to socially optimal (Result 1), they both lead to reduced payoffs. Average realized payoffs in the EX treatments are close to the predicted levels, and for EX-High they even exceed the predicted level. This results from the fact that deviations from the predicted investment level are typically in the direction of the efficient level. A similar picture emerges for the RE treatments. Breach inefficiencies are typically negligible, except in the RE-High treatment.

5 Discussion

In five of the six treatments the equilibrium point predictions fare very well; average investment levels are close to the predicted investment levels and breach decisions are almost always in line with own payoff maximization. The single exception in which the equilibrium predictions receive less support is the RE-High treatment. Here the average investment level equals 75 while 80/85 is predicted and most of the unpredicted breach decisions occur in this treatment. As Result 3 shows, the lower average investment level in the RE-High treatment results from the fact that in a substantial number of investment decisions $I = 50$ is chosen. In this section we consider several explanations for these deviations.

A rationale for buyers to invest 50 rather than 80/85 lies in the anticipation of negative reciprocity. Reciprocity entails that one is willing to forgo some money in order to punish behavior that is considered as unkind or to reward behavior that is considered as kind. A growing body of experimental economics studies points to the importance of reciprocity (Fehr and Gächter, 1998 and Fehr and Schmidt, 1999). A buyer who invests 80/85 does so to prevent the seller from breaching. The seller has reason to perceive this high investment level as an unkind action. It implies a large damage payment and because of that the seller cannot benefit from the otherwise favorable high outside bid of 7,000. But under the RE-treatment the

buyer's payoffs depend on the seller's breach decision, which gives the seller the opportunity to punish the buyer for overinvesting by breaching the contract. A buyer who anticipates this punishment and wants to avoid it will choose $I = 50$ when $p = \frac{3}{5}$ rather than the predicted $I = 80$ or $I = 85$. Levels between 50 and 80/85 (or above 80/85) can also be interpreted as unkind and may trigger the seller to breach. At $I = 50$ the buyer still reaps the benefits from being completely insured. This reciprocity mechanism also explains why sellers in the RE-High treatment sometimes breach when the outside bid is high (even when this costs them money).

To address this mechanism more formally, we conducted an additional (*seller-is-computer*) session. In this session of the RE treatment all subjects have the role of buyer. They play against the computer which has the role of seller. The computer always chooses the option that gives it the highest payoff, implying that it never breaches in order to punish the buyer for overinvesting when this incurs a cost.²³ Subjects were informed about this. Subjects played four blocks of eight rounds, where in the first and third block $p = \frac{3}{5}$, and in the second and fourth block $p = \frac{1}{5}$. The average investment level in this treatment equals 78.5 (with s.d. 7.6) when $p = \frac{3}{5}$, and 53.6 (with s.d. 8.1) when $p = \frac{1}{5}$. The frequencies of $I = 50$, $I = 80/85$ in the RE-High treatment are now equal to 9.7% and 80.0%, respectively. These figures should be compared with mean investment levels of 74.6 (s.d. 11.0) and 51.5 (s.d. 4.7) (cf. Table 3) and frequencies equal to 17.9% and 72.5%. For the RE-High treatment these differences are not significant when tested at the level of individuals' mean investment decisions, but they are significant at the 1%-level for individual investment decisions. This indicates that there is a difference in investment behavior between the standard treatments and the treatment in which the computer has the role of the seller.

Fairness or equity considerations provide no convincing explanation for these differences. A switch from $I = 85$ to $I = 50$ changes the expected payoffs of the buyer and the seller from 1,675 and 600 to 1,160 and 2940. This implies that preferences have to be extremely altruistic to account for buyers who choose $I = 85$ when they play against the computer and $I = 50$ when they play against other subjects. And if buyers are very altruistic it would be better to invest $I = 40$ as this gives expected payoffs equal to 1,120 for

²³When $I = 80$ and the outside bid is high, the seller is indifferent between breaching and not breaching. In this case the computer chooses the two with equal probabilities. Subjects are informed about this.

the buyer and 3,480 the seller. As choices of $I = 40$ are not observed in the RE-High treatment, we attribute the difference between the standard RE-sessions and the seller-is-computer RE-session to the anticipation of negative reciprocity.

The fact that when playing against the computer almost 10% of the investment choices equal 50 is somewhat uneasy because it suggests that not all the $I = 50$ choices in the standard RE-High treatment can be attributed to anticipation of negative reciprocity. Closer inspection of the results of the seller-is-computer session reveals, however, that the 10% of $I = 50$ choices in the RE-High treatment should be attributed to a few subjects who frequently make mistakes and mix up the optimal choices of the High and the Low treatments. The same subjects who often chose $I = 50$ in the RE-High treatment, chose $I = 80/85$ in the RE-Low treatment. As a result the frequency of $I = 80/85$ in the RE-Low treatment in the seller-is-computer session equals 11.3%, while in the standard RE-Low treatment this is only 4.8%.²⁴ An explanation for this difference might be that in the seller-is-computer session subjects do not interact so that subjects who mix up the RE-High and RE-Low treatments never see the decisions of others. It appears thus that the findings of the seller-is-computer session of the RE-treatment are more biased due to subjects making errors than was the case in the standard RE-treatment.²⁵

The interesting related question is whether buyers' anticipation of negative reciprocity in the standard RE-High treatment is justified. Recall that sellers typically base their breach decision on own payoff maximization. Although one might expect sellers to reciprocate negatively when the buyer invests 85 or more, this occurs in only 10 out of 158 cases. Apparently the seller is not offended enough by the overinvestment or finds a punishment in the form of breaching too costly. It is instructive to compare these results with those where the investment equals 80 and the outside bid is high. In that case the seller's payoff is independent of the breach decision ($b = f + \delta_{RE}(80)$). In 21 out of 54 cases the seller then chooses not to breach,

²⁴This type of errors are poorly captured by the quantal response model of McKelvey and Palfrey (1995, 1998). We estimated this model for the data of the standard RE-High treatment using a logit specification. Results show that the model clearly has difficulties tracking the realized frequency belonging to the investment level of 50. The Web Appendix provides details.

²⁵Other possible explanations for the frequent choice of $I = 50$ in the RE-High treatment are that 50 is the natural focal point as the mid-point in the permitted investment range of 0 to 100, or that risk aversion makes an investment choice of 50 desirable. The focal point explanation receives some support from the observation that in the LI-Low treatment $I = 50$ is the mode while $I = 40$ is the predicted investment level. This is weakened by the finding that in the LI-High treatment $I = 50$ is almost never chosen. Risk aversion has no bite as explanation as in the RE treatment $I = 50$ is a more risky choice than $I = 80/85$.

which suggests that these sellers don't feel offended by the buyer's overinvestment decision. Otherwise they could have punished the buyer at no cost. In the other 33 cases the seller uses the opportunity to costlessly punish the buyer. But of course, the 21-33 division might as well reflect that the sellers randomize over two equivalent alternatives. In any case, raising the investment level from 80 to 85 clearly prevents breaching under reliance damages. Sellers are typically not willing to punish the buyer when it is costly to do so.

The above results with respect to sellers' observed breach behavior suggest that preventing breach almost surely through a choice of $I = 85$ is beneficial to the buyer, compared with investing either $I = 80$ or $I = 50$. Indeed, for the RE-High treatment buyers' average payoffs equal 1,603 when the investment equals 85, 1,236 for an investment of 80, and 1,079 when the investment equals 50. (Equilibrium predictions for the expected payoffs of the buyer equal 1,675 when $I = 85$ and 2,000 when $I = 80$ and the seller never breaches, and 1,160 when $I = 50$.) Hence, given sellers' behavior, it is not in a buyer's best interest to invest 50.

6 Conclusion

Breach remedies serve an important role in protecting relationship-specific investments. The theoretical literature predicts that in various situations some commonly used types of breach remedies protect too well, in the sense that they induce overinvestment. The two driving forces behind this result are the full insurance motive and the breach prevention motive. Whether these two motives are of any practical significance and indeed induce overinvestment is an empirical issue.

The experiment covers three different breach remedies: liquidated damages, expectation damages and reliance damages. For each remedy, two treatments are distinguished: one in which the probability of a high outside bid is low and one in which this probability is high. The resulting 3×2 design allows us to base conclusions concerning the relevance of the two overinvestment motives on a comparison of the comparative statics results within breach remedies, as well as on a comparison of investment levels across remedies.

The results provide convincing evidence that both motives play a role. But the extent to which the breach prevention motives affect the investment level is somewhat less than predicted. We attribute this to

some investors anticipating that a high level of investment may trigger negative reciprocity. Although there indeed seems some reason to anticipate negative reciprocity, it turns out that in only a very few cases the non-investing party is prepared to bear the costs of punishing the investor for her overinvestment.

The finding that overinvestment occurs when damages are determined on the basis of expectation damages or reliance damages calls for some caution with the use of these types of damages. Especially in circumstances where a favorable outside opportunity is rather likely, expectation damages and reliance damages can substantially reduce efficiency. Appropriately chosen liquidated damages are likely to perform much better in that case.

This paper studied a condensed form of the holdup game which omitted the renegotiation stage. While this renegotiation stage is essential for the holdup problem to occur, the predictions with regard to the overinvestment motives carry over to the setup without renegotiation. Now that this paper has established that these motives are indeed at work in the simple setup, future experiments can build on this to investigate whether this is also true in the more realistic setting with a renegotiation stage.

References

- Che, Y.-K. and T.-Y. Chung (1999). Contract damages and cooperative investment. *Rand Journal of Economics* 30, 84–105.
- Chung, T.-Y. (1992). On the social optimality of liquidated damage clauses: An economic analysis. *Journal of Law, Economics & Organization* 8, 280–305.
- Chung, T.-Y. (1995). On strategic commitment: Contracting versus investment. *American Economic Review (Papers and Proceedings)* 85, 437–441.
- Cooper, R., D. DeJong, R. Forsythe, and T. Ross (1990). Selection criteria in coordination games. *American Economic Review* 80, 218–233.
- Cooter, R. and T. Ulen (1997). *Law and Economics* (Second ed.). Addison-Wesley Reading.

- Edlin, A. (1997). Breach remedies. Working paper, NBER.
- Edlin, A. and S. Reichelstein (1996). Holdups, standard breach remedies, and optimal investment. *American Economic Review* 86, 478–501.
- Fehr, E. and S. Gächter (1998). Reciprocity and economics: The economic implications of *homo reciprocans*. *European Economic Review* 42, 845–859.
- Fehr, E. and K. Schmidt (1999). A theory of fairness, competition, and cooperation. *Quarterly Journal of Economics* 114, 817–868.
- MacLeod, W. and J. Malcomson (1993). Investment, holdup and the form of market contracts. *American Economic Review* 83, 811–837.
- Mahoney, P. (1995). Contract remedies and options pricing. *Journal of Legal Studies* 24, 139–162.
- Malcomson, J. (1997). Contracts, hold-up, and labor markets. *Journal of Economic Literature* 35, 1916–1957.
- McKelvey, R. and T. Palfrey (1995). Quantal response equilibria for normal form games. *Games and Economic Behavior* 10, 6–38.
- McKelvey, R. and T. Palfrey (1998). Quantal response equilibria for extensive form games. *Experimental Economics* 1, 9–42.
- Millner, E. and M. Pratt (1991). Risk aversion and rent-seeking: An extension and some experimental evidence. *Public Choice* 69, 81–92.
- Posner, R. A. (1977). *Economic Analysis of Law* (second ed.). Boston: Little, Brown and Company.
- Rogerson, W. (1984). Efficient reliance and damage measures for breach of contract. *Rand Journal of Economics* 15, 39–53.
- Shavell, S. (1980). Damage measures for breach of contract. *Bell Journal of Economics* 11, 466–490.

Shavell, S. (1984). The design of contracts and remedies for breach. *Quarterly Journal of Economics* 99, 121–148.

Spier, K. and M. Whinston (1995). On the efficiency of privately stipulated damages for breach of contract: entry barriers, reliance, and renegotiation. *Rand Journal of Economics* 26, 180–202.

Walker, J., V. Smith, and J. Cox (1990). Inducing risk-neutral preferences: An examination in a controlled market environment. *Journal of Risk and Uncertainty* 3, 5–24.

Williamson, O. (1985). *The economic institutions of free capitalism*. New York: Free Press.

Appendix

A Derivation of the efficient level of investment

We have to solve the following maximization problem:

$$\max_I S(I) = (1 - p)(V + v \cdot I) + p \cdot \max\{V + v \cdot I, b_h\} - I^2$$

First observe that an investment level of $I = (b_h - V)/v$, such that $V + v \cdot I = b_h$ and the max term is at its kink, can never be optimal. For this investment level the right derivative of $S(I)$ equals $v - 2I$, while the left derivative equals $(1 - p)v - 2I$. The right derivative is thus larger than the left derivative for this investment level, which immediately yields that $I = (b_h - V)/v$ cannot be the optimum.

Therefore, only two cases have to be considered. First, assume that $b_h > V + v \cdot I$ for the efficient level of investment. It immediately follows that $I = \frac{1}{2}(1 - p)v$ in that case. For the assumption to hold it is required that $b_h > V + \frac{1}{2}(1 - p)v^2$. Second, suppose $b_h < V + v \cdot I$ for the socially optimal level of investment. Then $I = \frac{1}{2}v$ and it is required that $b_h < V + \frac{1}{2}v^2$. Now when $V + \frac{1}{2}(1 - p)v^2 < b_h < V + \frac{1}{2}v^2$ both candidates for the optimum exist. Expected net social surplus when $I = \frac{1}{2}(1 - p)v$ equals $(1 - p)V + p \cdot b_h + \frac{1}{4}(1 - p)^2v^2$, while in case $I = \frac{1}{2}v$ it equals $V + \frac{1}{4}v^2$. Comparing these two expected payoffs it immediately follows that

when $b_h > V + \frac{1}{4}(2-p)v^2$ the former is strictly larger, and when $b_h < V + \frac{1}{4}(2-p)v^2$ the latter is strictly larger. The result immediately follows. QED.

B Derivation of the equilibrium levels of investment

We have to solve the following maximization problem:

$$\max_I \pi(I) = (1-p)(V + v \cdot I - f) + p \cdot \delta(I) \cdot 1_{\{I \in B(I)\}} + p \cdot (V + v \cdot I - f) \cdot (1 - 1_{\{I \in B(I)\}}) - I^2$$

Here $1_{\{I \in B(I)\}}$ is used to denote the indicator function which is equal to 1 iff $b_h \in B(I)$ for the value of I chosen, and 0 otherwise. The function simply indicates whether breach occurs when $b = b_h$ for the particular I chosen. We next consider the three different breach remedies separately.

- (LI). When $\delta_{LI} < b_h - f$ the seller breaches (only) when $b = b_h$. The buyer thus obtains $(1-p)(V + v \cdot I - f) + p \cdot \delta_{LI} - I^2$. We directly get $I_{LI} = \frac{1}{2}(1-p)v$. In case $\delta_{LI} > b_h - f$ the seller never breaches. Thus $I_{LI} = \frac{1}{2}v$.
- (EX). Here we have $\delta_{EX}(I) = V + v \cdot I - f$, such that $\pi(I) = V + v \cdot I - f - I^2$. We immediately get $I_{EX} = \frac{1}{2}v$.
- (RE). There are two relevant ranges for I to consider. In the range where $I < \sqrt{b_h - f}$ the seller breaches the contract (only) when $b = b_h$. The buyer's expected payoff is then $(1-p)(V + v \cdot I - f - I^2)$. In case $I \geq \sqrt{b_h - f}$ the seller never breaches and the buyer obtains $V + v \cdot I - f - I^2$. Given these two ranges, in principle two relevant different situations have to be distinguished (ignoring knife-edge cases): $\sqrt{b_h - f} \leq \frac{1}{2}v$ and $\frac{1}{2}v < \sqrt{b_h - f}$. (Note that $\frac{1}{2}v$ equals the investment level the buyer would have chosen in the absence of possible breach of contract.) Now, our assumption that $f < V$ together with Assumption 1 entails that $b_h - f \geq \frac{1}{4}v^2$, such that the first situation cannot occur. Only the second situation of $\frac{1}{2}v < \sqrt{b_h - f}$ remains. Here the seller would surely breach if the buyer chose investment level $I = \frac{1}{2}v$ and b turned out to be high ($b = b_h$). The buyer may want to forestall such a breach

by choosing $I = \sqrt{b_h - f}$ instead. The equilibrium level of investment immediately follows from comparing the expected payoffs under these two levels of investment: $\pi(\frac{1}{2}v) = (1-p)(V + \frac{1}{4}v^2 - f)$ and $\pi(\sqrt{b_h - f}) = V + v\sqrt{b_h - f} - b_h$. QED.

C Summary of the instructions

This experiment consists of 32 rounds. At the beginning of each round the participants are paired in couples. The division into couples is chosen such that it is impossible that you are paired with the same other participant in two consecutive periods. It also holds that within each of the four consecutive blocks of eight rounds viz. rounds 1 up to 8, rounds 9 up to 16, rounds 17 up to 24 and rounds 25 up to 32 you will never be paired with the same other participant in more than one round. Whenever you meet the same participant again is unpredictable. With whom you are paired within a particular round is always kept secret from you.

One of the participants in a pair has role A, the other has role B. Within a round you will keep the same role. What exactly your role is, you will hear at the beginning of each round. Over the rounds your role varies. This variation is chosen such that you will be assigned the role of A in exactly half of the total number of rounds, and the role of B in the other half.

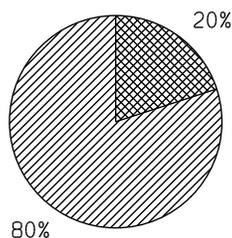
Each of the 32 rounds consists of 3 stages. In stage 1 the participant with role A takes a decision. In stage 3 the participant with role B makes a decision. In stage 2 a disk is turned around by the computer, in order to determine the color that applies in this round. During the three stages of one round you remain to be coupled with the same other participant. The three stages take the following form:

1. Participant A within a couple chooses the amount T. This amount has to be between 0 and 100 and, moreover, has to be a multiple of 5. After A has made his/her decision, B is informed about this choice. The choice of A for a particular amount T influences the final payoffs of both participants within a couple. Exactly how this dependency is, will be explained below when we discuss stage 3.
2. In order to determine the color that applies in this round, a disk is turned around by the computer. When the disk has come to a stop, it will point at a particular color: blue or yellow. The color

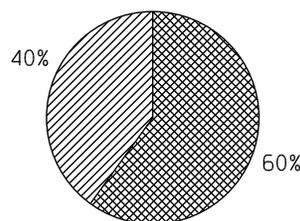
indicated by the disk is communicated to both participants within a pair. This color co-determines the number of points the participants receive at the end of the round. The probability that the disk will point at yellow depends on the number of the round. The total number of 32 rounds is divided into four blocks of 8. In the rounds 1 up to 8 and the rounds 17 up to 24 the probability of obtaining yellow is 20%. In the rounds 9 up to 16 and 25 up to 32 the probability of obtaining yellow is 60%. The two disks are reproduced below.

- Participant B chooses between two options: X and Y. After participant B has made his/her choice, A is informed about this choice. The rounds then comes to an end for both participants within a couple.

DISK BLOCK 1 AND 3
(rounds 1-8 and 17-24)



DISK BLOCK 2 AND 4
(rounds 9-16 and 25-32)



The general table appearing at the top of the additional sheet handed out (shown below) reflects the number of points both players have earned in the particular round. The number of points received depends on A's choice of amount T in stage 1, the color indicated by the disk in stage 2 (blue or yellow), and B's choice in stage 3 (X or Y). In this general table you have to fill in yourself the particular value of T chosen by A in order to obtain the appropriate number of points. You can also make direct use of the specific table that applies for the particular value of T chosen by A. For each possible choice of T $\{0, 5, \dots, 100\}$ the regarding specific table is also printed on the additional sheet. (In the upper left corner of these specific tables you will find the relevant value of T in **bold**.)

At the start of the experiment you receive 6000 points for free. At the end of the experiment you will be paid in guilders, based on the total number of points you earned. The conversion rate is such that 1500

points in the experiment correspond to one guilder in money.

General Table (LI). Number of points for both participants.

LI	Blue		Yellow	
	A	B	A	B
X	$400 + 100T - T^2$	600	$400 + 100T - T^2$	600
Y	$3400 - T^2$	-3400	$3,400 - T^2$	3,600

General Table (EX). Number of points for both participants.

EX	Blue		Yellow	
	A	B	A	B
X	$400 + 100T - T^2$	600	$400 + 100T - T^2$	600
Y	$400 + 100T - T^2$	$-400 - 100T$	$400 + 100T - T^2$	$6,600 - 100T$

General Table (RE). Number of points for both participants.

RE	Blue		Yellow	
	A	B	A	B
X	$400 + 100T - T^2$	600	$400 + 100T - T^2$	600
Y	0	$-T^2$	0	$7,000 - T^2$

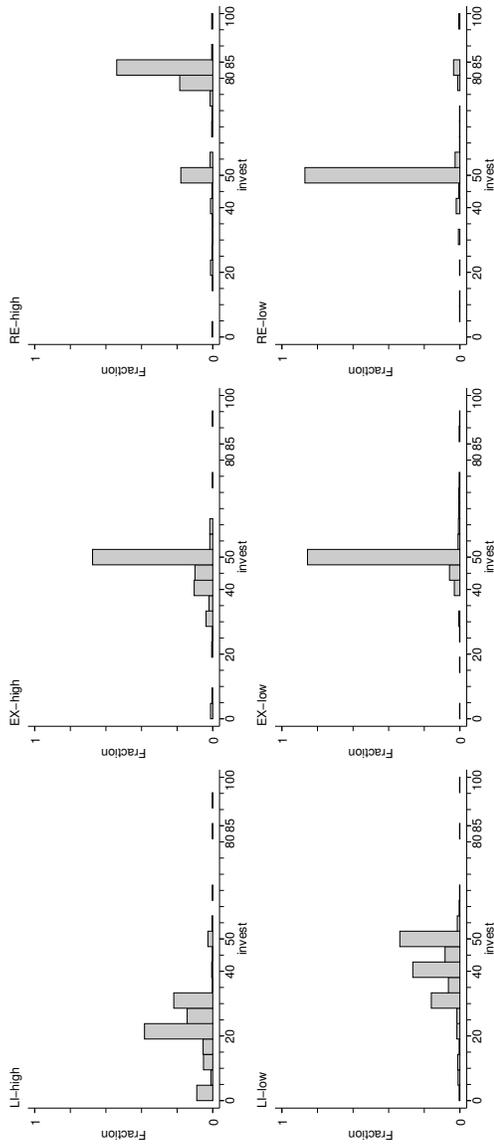
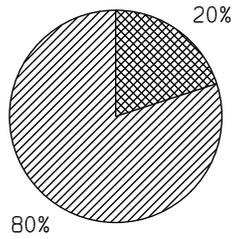


Figure 2: Distributions of investment levels by treatment

DISK BLOCK 1 AND 3
(rounds 1-8 and 17-24)



DISK BLOCK 2 AND 4
(rounds 9-16 and 25-32)

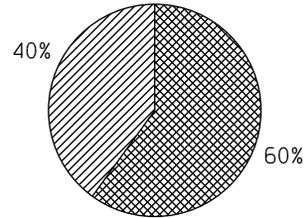


Table 1: Equilibrium predictions

Breach remedy	$\delta(I)$	Case	Equilibrium investment	Breach set	Breach set at $I_{\delta(I)}^*$
LI	δ_{LI}	$f + \delta_{LI} < b_h$	$\frac{1}{2}(1-p)v$	$\{b_h\}$	$\{b_h\}$
		$f + \delta_{LI} > b_h$	$\frac{1}{2}v$	\emptyset	\emptyset
EX	$V + v \cdot I - f$		$\frac{1}{2}v$	$b > V + vI$	$\{b_h\}$
RE	I^2	$(1-p)(V - \frac{1}{4}v^2 - f) > V - v\sqrt{b_h - f} - b_h$	$\frac{1}{2}v$	$b > f + I^2$	$\{b_h\}$
		$(1-p)(V - \frac{1}{4}v^2 - f) < V - v\sqrt{b_h - f} - b_h$	$\sqrt{b_h - f}$	$b > f + I^2$	\emptyset
Efficient			$\frac{1}{2}(1-p)v$	$b > V + vI$	$\{b_h\}$

Remark. For both LI and RE the first case applies for *optimal* contracts, i.e. f is such it maximizes the joint surplus of the buyer and the seller.

Table 2: Equilibrium point predictions

Breach remedy	Specification	Investment level		Breach set	Breach set at I_{eq}
		$p = \frac{1}{5}$	$p = \frac{3}{5}$		
LI	$\delta_{LI}(I) = 3,400$	40	20	$\{b_h\}$	$\{b_h\}$
EX	$\delta_{EX}(I) = 400 + 100 \cdot I$	50	50	$\{b > 1,000 + 100 \cdot I\}$	$\{b_h\}$
RE	$\delta_{RE}(I) = I^2$	50	80/85	$\{b > 600 + I^2\}$	$\{b_h\}, \emptyset$
Efficient		40	20	$\{b > 1,000 + 100 \cdot I\}$	$\{b_h\}$

Remark. $v = 100$, $V = 1,000$, $f = 600$, $b_l = 100$, $b_h = 7,000$, $p_1 = \frac{1}{5}$, $p_2 = \frac{3}{5}$ and $\delta_{LI} = 3,400$.

Table 3: Mean investment levels by treatment and tests for equality

Breach remedy	Probability b_h		Signrank tests (p -values) $p = \frac{1}{5}$ vs. $p = \frac{3}{5}$
	$p = \frac{1}{5}$	$p = \frac{3}{5}$	
LI	40.84 [40] (6.01)	21.72 [20] (5.78)	.0000 .0273
EX	49.76 [50] (3.26)	46.74 [50] (5.21)	.0000 .0277
RE	51.51 [50] (4.69)	74.64 [80/85] (11.01)	.0000 .0277
	Ranksum tests (p -values)		
LI vs. EX	.0000 <i>.0038</i>	.0000 <i>.0039</i>	
LI vs. RE	.0000 <i>.0039</i>	.0000 <i>.0038</i>	
EX vs. RE	.0139 <i>.0038</i>	.0000 <i>.0103</i>	

Remark. The p -values in normal font are based on mean investment levels of individuals, p -values in italics are based on mean investment levels per group.

Table 4: Breach decisions by breach remedy and outside bid

Breach remedy	Action	Outside bid b		
		$b < f + \delta(I)$	$b = f + \delta(I)$	$b > f + \delta(I)$
LI	No breach	567	0	7 (7)
	Breach	9 (9)	0	377 (2)
EX	No breach	576	7	4 (4)
	Breach	3 (3)	1 (1)	369
RE	No breach	720	21	5 (4)
	Breach	14 (14)	33 (33)	167 (8)

Remark. Non-equilibrium choices are bold faced. Inefficient choices are in parentheses.

Table 5: Joint payoffs

	Predicted expected	Average realized	Investment inefficiency	Breach inefficiency	Residual inefficiency	(1)/S(I*)	(2)/S(I*)
	(1)	(2)	(3)	(4)	(5)		
LI-Low	3,800	3,652	112	65	-29	1	.96
LI-High	5,000	4,812	121	65	2	1	.96
EX-Low	3,700	3,652	123	27	-2	.97	.96
EX-High	4,100	4,189	785	19	7	.82	.84
RE-Low	3,700	3,595	189	27	-11	.97	.95
RE-High	2,275	2,554	2,199	255	-8	.46	.51

Remarks. $S(I^*)$ bold faced. It holds that $S(I^*) - (2) = (3) + (4) + (5)$.