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# Breach Remedies Inducing Hybrid Investments <sup>\*</sup>

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## Abstract

We show that parties in bilateral trade can rely on the default common law breach remedy of ‘expectation damages’ to simultaneously induce first-best relationship-specific investments of both the selfish and the cooperative kind. This can be achieved by writing a contract that specifies a sufficiently high quality level. In contrast, the result by Che and Chung (1999) that ‘reliance damages’ induce the first best in a setting of purely cooperative investments, does not generalize to the hybrid case.

We also show that if the quality specified in the contract is too low, ‘expectation damages’ do not necessarily induce the ex-post efficient trade decision in the presence of cooperative investments.

*Keywords:* breach remedies, incomplete contracts, hybrid investments, cooperative investments, selfish investments.

*JEL-Classification:* K12, L22, J41, C70.

## 1 Introduction

A risk-neutral buyer and seller contract for the future delivery of a good. Before delivery can take place, the seller makes an investment that has no value to the outside market but that decreases the seller’s cost of production *and* increases the future value of the good to

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the buyer. That is, the investment is *hybrid*, combining cooperative investments in the sense of Che and Chung (1999) with selfish investments as traditionally analyzed in the literature (see, e.g., Chung, 1991; Aghion, Dewatripont and Rey, 1994; Edlin and Reichelstein 1996; Shavell, 1980, 1984; Rogerson, 1984).

Hybrid investments are highly relevant in the real world. For example, suppliers frequently obtain new machines not only to decrease their cost of production but also customize parts for their buyers, even when “specific investments ... have to be incurred to implement such customization” (Asanuma, 1989 p. 14). Moreover, Nishiguchi (1989 p.138) describes how suppliers send engineers to work with their buyers (automakers) in design and production who “play innovative roles [...] in gathering information about [the automakers’] long-term product strategies” (see also Che and Hausch, 1999 p.127).<sup>1</sup>

We develop a model where the parties write a contract governed by standard *legal breach remedies*. Under *expectation damages* the parties write a contract specifying a *price* for future trade and the *quality* of the good to be traded. If breach occurs, where either the seller fails to deliver or the buyer fails to accept the good, or the seller delivers a good of inadequate quality, the breached-against party can ask for expectation damages at trial.<sup>2</sup> Under this commonly-applied legal remedy, the victim of breach receives a payment that makes him as well off as performance would have. We show that, under this legal regime, the contract induces first-best investment incentives and the efficient ex-post breach decision when the parties set the quality required under the contract sufficiently high. This result holds independent of whether parties can renegotiate. However, if the quality specification

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<sup>1</sup>Other examples include the famous General Motors - Fisher Body case, which deals with Fisher Body’s decision to build a plant adjacent to General Motors. Such an arrangement offered benefits to both parties by lowering shipping costs *and* improving supply reliability (see Che and Hausch, 1999). Also consider the example of Marks & Spencer, which routinely organizes joint trips to trade shows with its suppliers. The trips enhance mutual understanding and help both parties to identify new products that they could develop cooperatively. By facilitating bilateral communication, Marks & Spencer adds valuable items to its product line while lowering the risk of costly reengineering of products for the suppliers (see Kumar, 1996).

<sup>2</sup>In the absence of contractual protection, the parties negotiate the terms of trade after investments are sunk and after the quality of the product is revealed. Unless the investing party has all the bargaining power, that party can only internalize a fraction of the investment benefit in such negotiations. Recognizing this potential for hold-up, the seller invests less than is socially desirable (Williamson, 1979, 1985; Grout, 1984; Grossman and Hart, 1986; Hart and Moore, 1988).

is set at an intermediate level, investment incentives are inefficient and the standard result (see, e.g., Posner, 1977; Shavell, 1980; Kornhauser, 1986; Craswell, 1988) that expectation damages induce the ex-post efficient breach may no longer hold. The result generalizes Edlin (1996) and Stremitzer (2012) who had analyzed the expectation damages regime in a setting of purely selfish and purely cooperative investments, respectively.

What makes this result interesting is that another well known efficiency result for this setting, due to Che and Chung (1999), cannot be generalized to the hybrid case. Che and Chung (1999) assume that parties can write a contract in which they stipulate the *price* of the good to be traded and an *up-front payment*. If breach occurs, under which the buyer refuses to accept the good, the seller can ask for *reliance damages*, i.e., he is reimbursed his non-recoverable investment expenses. Che and Chung (1999) show that there exists a price for which the contract induces the first best if renegotiation is possible. Yet, the logic of the argument cannot be extended to the hybrid setting. Indeed, it is always possible to construct examples where reliance damages induce overinvestment regardless of price. Although the precise argument is more complicated, this negative result is driven by the well known insight that reliance damages induce overinvestment if investments are purely selfish (Shavell, 1980; Rogerson, 1984). For this reason, it is not surprising that overinvestment occurs when investment is sufficiently selfish.<sup>3</sup> Finally, we consider ‘liquidated damages’ under which the parties stipulate fixed monetary damages that have to be paid if the contract is breached. In contrast to Che and Chung’s (1999) setting, where the seller underinvests, we demonstrate that the parties can attain the first best if investment is sufficiently selfish. This result bridges the gap between Che and Chung (1999) and the selfish investment literature (Cooter, 1985; Chung, 1992; Spier and Whinston, 1995) in which an optimal liquidated damages contract achieves the efficient outcome.

This article is organized as follows: In the next subsection, we relate our work to the preexisting literature. Section 2 describes our model and Section 3 derives the socially

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<sup>3</sup>That is, if the effect of seller’s investment on the cost of production is sufficiently large relative to the effect on the good’s quality.

optimal level of investment. We then show in Section 4, that the argument by Che and Chung (1999) on the efficiency of reliance damages cannot be extended to the hybrid case. In Section 5, we consider liquidated damages and demonstrate that the efficient outcome can be attained if investment is sufficiently selfish. Section 6 contains our main result that first-best investment levels can be achieved under expectation damages if the quality required under the contract is set sufficiently high. If not, investment incentives will be inefficient and expectation damages may even fail to induce the efficient ex-post trade decision. Section 7 concludes.

## 2 Related literature

In their seminal article Che and Hausch (1999), allow for hybrid investments and prove for a special informational setting where no signal of investment is verifiable that, if investments are sufficiently cooperative, contracting becomes irrelevant, that is, there exists no contract which achieves a better outcome than writing no contract at all. In contrast, Che and Chung (1999), who deal with legal breach remedies, consider a different informational set-up and only allow for *purely* cooperative investments. Cooperative investments were first studied in an incomplete contract setting by MacLeod and Malcolmson (1993) and are also referred to as “cross investments” (e.g. Guriev, 2003) or “investments with externalities” (e.g. Nöldeke and Schmidt, 1995). Other articles that consider cooperative investments include, e.g., Bernheim and Whinston (1998), Maskin and Moore (1999), De Fraja (1999), Rosenkranz and Schmitz (1999), Segal and Whinston (2002), and Roider (2004).

There has been an ongoing debate about the efficiency properties of expectation damages, the default breach remedy in common law. Che and Chung (1999) argue that ‘expectation damages’ perform very badly inducing *zero* cooperative investments. Yet, as Stremitzer (2012) has shown, this follows from their implicit assumption that the contract stays silent in terms of *required quality*, which will rarely be the case. Indeed, even if the parties do not stipulate anything explicit as to quality in their contract (express warranty), the court will do it for them by default, e.g., by requiring the good to serve its ordinary purpose (implied

warranty of merchantability, see Uniform Commercial Code Section 2-314). Taking this feature of real world contracting into account, Stremitzer (2012) shows that ‘expectation damages’ will always induce *positive* levels of cooperative investments. The remedy even achieves the first best if parties write a ‘Cadillac contract’, i.e., choose a very high quality specification. Edlin (1996) also analyses ‘Cadillac contracts’ in the context of expectation damages but makes a different point: He considers a setting where the seller makes *selfish* investments. In the absence of a contract, there will be underinvestment due to the hold-up problem. If, however, the contract stipulates the highest possible quality/quantity, and it is the buyer who breaches the contract, the seller will overinvest. This is because he is fully insured and fails to take into account the states of the world where it is inefficient to trade (This is a version of the ‘overreliance’ result by Shavell (1984) who implicitly assumes Cadillac contracts by modelling the trade decision as binary). To solve this problem, Edlin (1996) proposes to set the price so low, that it will always be the investing seller who breaches the contract. That makes him the residual claimant and provides him with efficient investment incentives. Yet, in order to make the seller accept a contract with such a low price, the buyer has to pay the seller a lump sum up front. By contrast, in our model, we are concerned with *hybrid* investments and need not rely on any up-front payments. Göller (2012) extends the results of Edlin (1996) and Stremitzer (2012) to bilateral cooperative investments. He demonstrates that it is optimal to write a so called “augmented Cadillac contract” that stipulates a cost- *and* a quality threshold. Because setting the quality threshold at Cadillac level ensures that the seller is a residual claimant regardless of how the cost threshold is set, the latter can be used to balance the incentives of the buyer. Schweizer (2006) shows that a regime of “bilateral expectation damages” also achieves first-best cooperative investment. His optimality result stems from the fact that the contract also specifies investment and that the non-investing party thus can claim damages if the counter-party underinvested relative to the level stipulated in the contract. To the best of our knowledge, our paper is the first article comparing the efficiency of expectation damages as opposed to other standard breach remedies if the seller’s investments are hybrid.

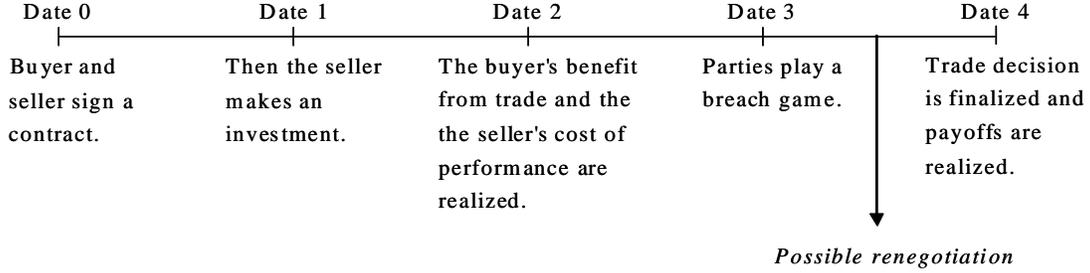


Figure 1: Timeline.

### 3 The model

Consider a buyer-seller relationship where risk-neutral parties potentially trade a good. At date 0, the parties sign a contract (see Figure 1). The contract specifies a fixed price,  $p$ , which has to be paid by the buyer if the seller performs in accordance with the contract and, in the case of expectation damages, a quality threshold,  $\bar{v}$ . Moreover, parties can specify a lump sum transfer,  $t$ , to split the expected gains from trade. At date 1, the seller makes a relation-specific investment,  $e \in \mathbb{R}_0^+$ , which stochastically determines the buyer's benefit from trade as well as the seller's cost of production. At date 2, both the buyer's benefit from trade,  $v$ , and the seller's potential cost of performance,  $c$ , are drawn from the intervals  $[0, v_h]$  and  $[c_l, c_h]$  by the conditional distribution functions  $F(\cdot|e)$  and  $G(\cdot|e)$  respectively.<sup>4</sup> At date 3, the parties play a breach game in which it is decided whether trade occurs or not. When renegotiations are possible, they are costless and can occur anytime between date 3 and date 4 when parties have to make the final trade decision. The potential renegotiation surplus is split at an exogenously given ratio with the seller receiving a share of  $\alpha \in [0, 1]$ .<sup>5</sup>

As an example, consider the case where an engineering firm develops a new motor for a

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<sup>4</sup>Note that both cost  $c$  and value  $v$  only materialize in the event of trade. Our assumption that no production costs are incurred before uncertainty is resolved reflects a distinction between investment and cost that is conventional. With regard to the example below, note that any investment into the creation of the construction plan is lost if the parties decide not to trade. The cost to produce the motor is, in contrast, only incurred after the construction plan is ready, i.e., uncertainty is resolved, and the parties agree to finalize trade.

<sup>5</sup>Note that the bargaining setup considered here and in Che and Chung (1999) differs from Rogerson (1984) who implicitly assumes that parties can only renegotiate prior to the buyer's breach decision. Also Lyon and Rasmusen (2004), MacLeod and Malcomson (1993) and Watson (2007) consider alternative bargaining models.

car manufacturer. In the first stage, the engineering firm invests in know-how and develops a construction plan. The know-how may reduce the costs of production and/or increase the quality of the motor. Once the construction plan is ready, the parties know the costs and benefits associated with the motor. Only then do they decide whether the motor shall be produced.

The informational requirements depend on the breach remedy the court applies. Under reliance damages, the court must be able to verify the seller's investment whereas, under expectation damages, it must be able to verify the buyer's valuation and the seller's variable costs. Note that this information is also sufficient to decide whether the quality of the product is below or above a certain quality threshold. While investment may be private information, everything else is observable and verifiable to all parties. Finally, the following technical assumptions apply throughout:

- **Assumption 1**  $F(\cdot|\cdot)$  and  $G(\cdot|\cdot)$  are twice continuously differentiable.
- **Assumption 2**  $F_e(\cdot|e) \leq 0$  and  $F_{ee}(\cdot|e) > 0$  for all  $v \in (0, v_h)$  and  $e \geq 0$ .
- **Assumption 3**  $G_e(\cdot|e) \geq 0$  and  $G_{ee}(\cdot|e) < 0$  for all  $c \in (c_l, c_h)$  and  $e \geq 0$ .
- **Assumption 4**  $F_e(v|0) = -\infty$  and/or  $G_e(c|0) = \infty$   
for all  $v \in (0, v_h)$  and for all  $c \in (c_l, c_h)$ .
- **Assumption 5**  $F_e(v|\infty) = 0$  for all  $v \in (0, v_h)$  and  $G_e(c|\infty) = 0$  for all  $c \in (c_l, c_h)$
- **Assumption 6**  $F_{v|c}((v|c)|e) = F_v(v|e)$  and  $G_{c|v}((c|v)|e) = G_c(c|e)$  for  $(c, v) \in \mathbb{R}^2$ .

Assumption 2 implies that an increase in  $e$  moves the distribution to the right at a decreasing rate in the sense that  $F(\cdot|e')$  first-order stochastically dominates  $F(\cdot|e)$  for any  $e' > e$ . In the same way, Assumption 3 implies that an increase in  $e$  moves the distribution to the left at a decreasing rate in the sense that  $G(\cdot|e')$  first-order stochastically dominates  $G(\cdot|e)$  for any  $e' < e$ . Assumptions 4 and 5 ensure an interior solution to the social welfare problem while Assumption 6 implies that variable costs,  $c$ , and the buyer's valuation,  $v$ , are

stochastically independent. To save notation, we assume that the highest possible benefit of the buyer is equal to the highest possible realization of variable cost,  $v_h = c_h$ .<sup>6</sup>

## 4 Benchmark

We consider the socially optimal allocation as a benchmark. A social planner cares for two things: First, he wants parties to trade whenever trade is efficient ex-post,  $v \geq c$ . Second, given the ex-post optimal trade decision, he wants the seller to choose the investment level  $e^*$ , which maximizes the expected gains of trade:

$$e^* \in \arg \max W(e) = \int_{c_l}^{c_h} \int_c^{v_h} (v - c) F_v(v|e) dv G_c(c|e) dc - e. \quad (1)$$

Twice integrating by parts and differentiating, the efficient investment level,  $e^*$ , can be characterized by the following first-order condition:

$$W'(e^*) = \int_{c_l}^{c_h} ([1 - F(c|e^*)] G_e(c|e^*) - F_e(c|e^*) G(c|e^*)) dc - 1 = 0. \quad (2)$$

We assume that  $W(e)$  is strictly quasi-concave in  $e$ . This ensures that  $e^*$  is unique and well defined.

## 5 Reliance damages with renegotiations

Che and Chung (1999) show that, in a setting of purely cooperative investments, there exists a price such that reliance damages induce the first best if renegotiation is possible. On the other hand, Shavell (1980) and Rogerson (1984) show that reliance damages perform poorly

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<sup>6</sup>This assumption is not crucial for our results. If it was relaxed, say  $v_h \geq c_h$ , a contract, which specifies a quality specification above the highest possible realization of quality still ensures that the seller is a residual claimant of the trade relationship and thus has efficient incentives to invest under expectation damages. Under reliance damages, our overinvestment result is driven by the fact that the seller internalizes a fraction of the cost decreasing effect of investment even in those situations where trade is inefficient from a social perspective. This effect continues to exist if  $v_h \geq c_h$ . To obtain our optimality result under liquidated damages it is crucial that the seller has an incentive to overinvest if the gap between price and damages is small. Because he has an incentive to underinvest if this gap is large, this implies that there exists an intermediate gap that induces optimal investment. That the seller indeed overinvests if the gap is small is only so if investment is sufficiently selfish. He then internalizes a fraction of the cost decreasing effect of investment even if trade is undesirable from a social perspective. As before, this effect continues to exist if  $v_h \geq c_h$ .

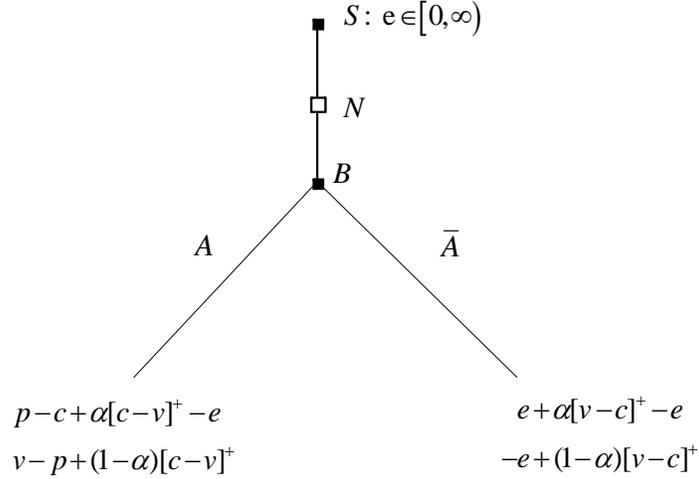


Figure 2: Subgame induced by reliance damages if renegotiations are possible.

in an environment of selfish investments, inducing overreliance. These two results lead us to the question how reliance damages perform in a hybrid setting, which contains aspects of both cooperative and selfish investments. We find that it is not possible to extend the result by Che and Chung (1999) to the hybrid case. Indeed, reliance damages may fail to induce the first best regardless of price.<sup>7</sup> To show this, we analyze the game induced by a simple contract specifying price,  $p$ , and some lump sum transfer,  $t$ , if that contract is governed by reliance damages (see Figure 2). Under reliance damages, the seller is reimbursed his reliance expenses  $e$  if the buyer announces breach ( $\bar{A}$ ). If the buyer is willing to accept the good and trade occurs, the seller and the buyer receive  $p - c$  and  $v - p$ , respectively.<sup>8</sup> Moreover, whenever the buyer's decision is ex post inefficient, the parties renegotiate towards the ex post efficient trade decision and split the potential renegotiation surplus with the seller receiving a fixed share of  $\alpha \in [0, 1]$ . For example, if  $v > c$ , but the buyer announces breach, the seller derives  $\alpha[v - c]^+$  from renegotiations, where we shall frequently use the notation

<sup>7</sup>Since Che and Chung (1999) have already shown that 'reliance damages' fail to induce the first best in a setting of purely cooperative investments if renegotiation is not possible, we focus on the case where renegotiation is possible.

<sup>8</sup>In order to stay close to the setting studied by Che and Chung (1999), we take over their assumption that the buyer can legally compel the seller to deliver.

$[\cdot]^+ = \max[\cdot, 0]$ . Hence, the buyer will announce breach if and only if

$$-e + (1 - \alpha)[v - c]^+ > v - p + (1 - \alpha)[c - v]^+ \quad (3)$$

or equivalently if

$$v < \hat{v}^{RD} \equiv \min \left[ \frac{p - e - c}{\alpha} + c, v_h \right]. \quad (4)$$

So far the analysis is identical to Che and Chung (1999) except that cost of production is deterministic in their setting while it is stochastic in ours. Let us now revisit the intuition behind Che and Chung's result that there always exists a price which induces first-best investment in a setting of purely cooperative investments. First, note that the seller's expected payoff decreases in  $e$ , conditional on the buyer accepting the good. Since the buyer will never breach if the price is set sufficiently low, the parties can implement zero investment by specifying  $p = 0$ . A very high price, on the other hand, ensures that the buyer always announces breach. Given the reliance damages remedy, the seller is sure to regain his investment and, in addition, to receive a renegotiation surplus of  $\alpha[v - c]^+$ , which is increasing in  $e$ . Anticipating this, the seller invests as much as he can, overinvesting relative to the efficient level.<sup>9</sup> Hence, given that investment depends continuously on price, there must exist an intermediate price that induces first-best investment.

However, this simple intuition fails in a setting of hybrid investments. To see this, first consider the case where the parties specify a very high price. Again, the seller overinvests because his payoff  $\alpha[v - c]^+ + e - e$  is strictly increasing in  $e$ . Yet, even for  $p = 0$ , the seller may have an incentive to overinvest. If investment is hybrid, his cost of production is decreasing in  $e$ . We can prove the following proposition:

**Proposition 1** *If parties can stipulate a price,  $p$ , and a lump sum payment,  $t$ , and their contract is governed by reliance damages, a price inducing first-best hybrid investments does not always exist.*

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<sup>9</sup>Technically speaking, the seller's investment would be arbitrarily close to infinity since Che and Chung (1999) do not impose any wealth constraint but assume  $e \in R_0^+$ .

Proof: See the Appendix.

Even though the proof of Proposition 1 is rather tedious, the intuition behind it is straightforward. We can see from Figure 2 that if parties set the price very low, say at  $p = 0$ , the buyer always accepts delivery and, as in Che and Chung (1999), compels the seller to deliver. Thus, the seller's payoff is  $p - c$  for  $v \geq c$  and  $p - (1 - \alpha)c - \alpha v$  for  $v < c$ . Hence, his payoff always increases as cost becomes lower, while a benevolent social planner disregards the cost-decreasing effect of investment for  $v < c$ . It may thus occur that the seller overinvests at price  $p = 0$ . This is especially likely if the seller's bargaining power  $\alpha$  is low and investment mainly affects cost and only has marginal influence on quality  $v$ . Given this possibility, it suffices to show that a positive price will never induce the seller to invest less. This is true, as increasing the price only makes it more likely that the buyer announces breach.<sup>10</sup> Yet, the seller's payoff in case of breach  $\alpha[v - c]^+ + e - e$  is increasing in  $e$ . If the buyer always breached, investment incentives would even be indefinitely high. Therefore, investment incentives rise in  $p$ .

Hence, the efficiency result derived by Che and Chung (1999) for reliance damages in a setting of purely cooperative investments does not generalize to the hybrid case. In the next section, we consider liquidated damages under which underinvestment is the norm in Che and Chung's (1999) setting.

## 6 Liquidated damages with renegotiations

In this section, we analyze the performance of privately stipulated liquidated damages. As in Che and Chung (1999), a contract stipulates a price,  $p$ , fixed monetary damages that have to be paid if the contract is breached,  $\delta$ , and an up-front transfer,  $t$ . If the buyer announces to accept the good, the parties get, as before, their respective trade surpluses  $v - p$  and  $p - c$ . In contrast, if the buyer refuses to accept the good, she has to pay damages of  $\delta$  to the seller. If renegotiation is impossible, the situation is very similar to Che and Chung (1999).

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<sup>10</sup>If the price is smaller than  $(1 - \alpha)c_l$ , the buyer still always accepts delivery. Then, the seller invests the same amount as if a  $p = 0$  had been specified in contract.

The seller has positive investment incentives but the buyer's ex-post breach decision is not efficient. Thus, the first best is unattainable. Let us assume that costless renegotiation is possible, i.e. the parties share any potential ex-post bargaining surplus according to their bargaining power. Thus, the buyer announces breach if

$$-\delta + (1 - \alpha)[v - c]^+ > v - p + (1 - \alpha)[c - v]^+ \quad (5)$$

or equivalently if

$$v < \hat{v}^{LD} \equiv \min \left[ \frac{p - \delta - c}{\alpha} + c, v_h \right]. \quad (6)$$

We can prove the following proposition:

**Proposition 2** *Under liquidated damages, a price/damages combination inducing first-best hybrid investment does not always exist. The first best can be induced, however, if the cooperative effect of investment is sufficiently small relative to the selfish effect,*

$$(1 - \alpha) \int_{c_l}^{c_h} F(c|e^*)G_e(c|e^*) dc > - \int_0^{v_h} F_e(v|e^*) dv - (1 - \alpha) \int_{c_l}^{c_h} F_e(c|e^*)G(c|e^*) dc.$$

Proof: See the Appendix.

If the cooperative effect of investment dominates the selfish effect, we are in a situation similar to the one considered by Che and Chung (1999). The first best is unattainable and the parties cannot do better than to specify a large positive gap between price and damages to ensure that the buyer ex-post refuses to accept the good. The parties then renegotiate whenever it is socially desirable to do so. Consequently, the seller invests as if the parties did not write any contract at all. If the cooperative effect of investment is small, we are in a situation close to Spier and Whinston (1995). As before, if the gap between price and damages is large, the seller underinvests. In contrast, a sufficiently small gap ensures that the buyer always announces to accept. Then, the seller has, compared to a benevolent social planner, an incentive to overinvest. He internalizes the cost decreasing effect of investment even in those states of the world where trade is undesirable from a social perspective. In such states, the seller ex-post receives  $p - (1 - \alpha)c - \alpha v$ . Thus, his overinvestment incentives

are more severe if his bargaining power is low and if the cooperative effect of investment is small. Consequently, if the relationship between  $p - \delta$  and investment is continuous, there exists a price damages combination that induces first-best investment. At first glance, one might think that the more cooperative the investment is, the smaller the gap between price and damages should be stipulated. That is, however, only true as long as the seller does not underinvest in the extreme case where it is ex-ante known that the buyer ex-post accepts the good. If investment is sufficiently cooperative such that the seller underinvests independent of how price and damages are set, the optimal gap increases with the cooperativeness of investment.

Hence, liquidated damages induce the seller to underinvest if investment is sufficiently cooperative whereas reliance damages induce him to overinvest if investment is sufficiently selfish. In the next section, we show that it is, in contrast, possible to generalize the efficiency result derived for the expectation damages remedy in Stremitzer (2012).

## 7 Expectation damages

### 7.1 Expectation damages without renegotiations

In contrast to liquidated damages and reliance damages, where it is impossible to achieve ex-post efficiency if renegotiation is ruled out, a standard result of the law and economics literature suggests that the expectation damages remedy induces the ex-post efficient trade decision (see, e.g., Posner, 1977; Shavell, 1980; Kornhauser, 1986; Craswell, 1988). Hence, it may be possible to derive an efficiency result even without renegotiation.

Che and Chung (1999) assume that the contract stays silent in terms of required quality and show that expectation damages perform badly, inducing zero cooperative investments. In contrast, Stremitzer (2012) argues that even if the parties do not stipulate anything explicit as to quality in their contract (express warranty), the court will do it for them by default, e.g., by requiring the good to serve its ordinary purpose (implied warranty of merchantability). Let us now show that Stremitzer's (2012) optimality result can readily be extended to the

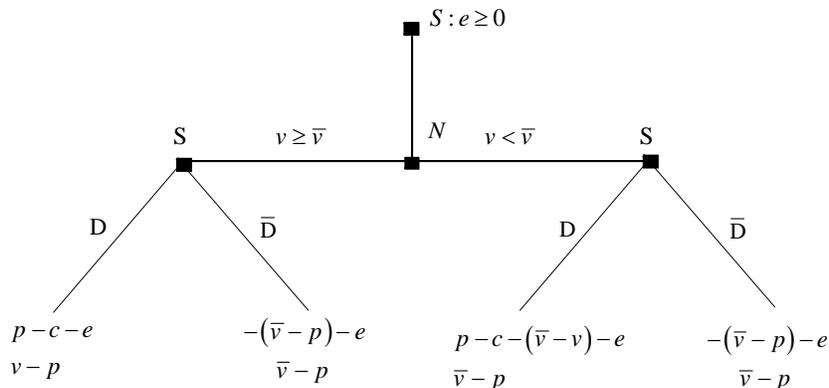


Figure 3: Subgame induced by expectation damages.

hybrid investments scenario. At the end of this section, we discuss his assumption of capped damages and what would change if the court awarded uncapped expectation damages as is commonly assumed in the literature.

Stremitzer (2012) assumes that the parties write a contract stipulating a fixed price,  $p$ , payable by the buyer upon the seller's performance and a quality level  $\bar{v}$  which specifies the required quality level under the contract and serves as a baseline for calculating damages if the seller delivers a non-conforming good.<sup>11</sup> For example, the contract could specify that a motor should not exceed a certain level of fuel consumption. Moreover, the parties can specify a lump sum transfer,  $t$ , to split the expected gains from trade (an instrument which we shall show they will not need in order to achieve the first best).

Assuming the buyer never refuses delivery,<sup>12</sup> the seller faces the following decision: If he decides to deliver the good, he receives the trade price but has to incur the costs of production and therefore receives a trade surplus of  $p - c$  (see Figure 3). Under expectation damages, the victim of breach receives a payment that makes him as well off as performance would have. It thus follows that if the good is of inferior quality,  $v < \bar{v}$ , the seller has to pay

<sup>11</sup>As is commonly assumed if courts apply expectation damages, the court can perfectly observe the buyer's benefit from trade or at least is able to form an unbiased estimate of it.

<sup>12</sup>Stremitzer (2012), who considers the performance of expectation damages in a setting of purely cooperative investment, demonstrates that legal remedies of contract law induce the buyer to always accept delivery. His reasoning can readily be extended to our setting, even though we consider hybrid investments.

damages amounting to  $\bar{v} - v$ . If the seller refuses to deliver, and assuming  $\bar{v} \geq p$ ,<sup>13</sup> the buyer receives his contractually assured trade surplus of  $\bar{v} - p$  regardless of the good's quality.

We will now solve the game by backwards induction. If  $v < \bar{v}$ , the seller will deliver if and only if it is ex-post efficient to do so ( $p - c - (\bar{v} - v) \geq -(\bar{v} - p) \iff v \geq c$ ). However, if the buyer's valuation turns out to be above the threshold,  $v \geq \bar{v}$ , the seller will deliver if and only if  $p - c \geq -(\bar{v} - p)$ , or equivalently  $c \leq \bar{v}$ . Hence, for  $\bar{v} < c < v$ , the seller's trade decision is ex-post inefficient. We can therefore write the following proposition:

**Proposition 3** *If parties specify a threshold below the highest possible realization of quality,  $\bar{v} < v_h$ , expectation damages fail to generally induce ex-post efficient trade.*

That expectation damages may fail to induce the ex-post efficient breach decision is due to the fact that Stremitzer (2012) introduces a cap on expectation damages: In case of non-delivery damages amount only to  $\bar{v} - p$ , even if  $v > \bar{v}$ . In absence of the quality threshold, the seller delivers if  $p - c \geq -(v - p)$  and thus whenever it is socially desirable to do so,  $v \geq c$ . Even though the parties stipulate a quality threshold in Stremitzer (2012), the aforementioned inefficiency does not occur in his setting of purely cooperative investment. This is because Stremitzer (2012) assumes  $\bar{v} > p > c$ . Thus, the interval where trade is ex-post inefficient,  $\bar{v} < c < v$ , is empty. If cost of production depend on investment, as in our setting, the interval  $\bar{v} < c < v$  is not necessarily empty and thus trade may be ex-post inefficient unless  $\bar{v} \geq c_h$ .

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<sup>13</sup>Note that  $\bar{v} < p$  would imply that the seller does not have to pay any damages if he decides not to deliver. One can readily show that it is indeed optimal for the parties to make sure that the price is lower than promised quality.

Given the seller's decision at date 3, he expects the following payoff at date 1:

$$\begin{aligned}
U^{ED}(e) &= \int_{c_l}^{\bar{v}} \int_{\bar{v}}^{v_h} (p - c) F_v(v|e) dv G_c(c|e) dc \\
&+ \int_{c_l}^{\bar{v}} \int_c^{\bar{v}} [(p - c) - (\bar{v} - v)] F_v(v|e) dv G_c(c|e) dc \\
&+ \int_{c_l}^{\bar{v}} \int_0^c -(\bar{v} - p) F_v(v|e) dv G_c(c|e) dc \\
&+ \int_{\bar{v}}^{c_h} \int_0^{v_h} -(\bar{v} - p) F_v(v|e) dv G_c(c|e) dc - e.
\end{aligned} \tag{7}$$

Integrating by parts and reorganizing allows us to simplify (7):

$$U^{ED}(e) = p - \bar{v} - e + \int_{c_l}^{\bar{v}} [1 - F(c|e)] G(c|e) dc. \tag{8}$$

The seller's optimal investment level,  $e^{ED}$ , can then be characterized by the following first-order condition:

$$U'^{ED}(e^{ED}) = \int_{c_l}^{\bar{v}} ([1 - F(c|e^{ED})] G_e(c|e^{ED}) - F_e(c|e^{ED}) G(c|e^{ED})) dc - 1 = 0. \tag{9}$$

We can derive the following proposition:

**Proposition 4** *If renegotiation is impossible and parties specify a sufficiently high quality threshold,  $\bar{v} \geq v_h$ , expectation damages induce the first best.*

**Proof.** If  $\bar{v} \geq v_h = c_h$ , we know from Proposition 3 that the seller's breach decision is ex-post efficient. Comparing expression (9) with the benchmark condition (2) we also see that  $\bar{v} \geq v_h = c_h$  ensures that the seller chooses the socially optimal investment level. ■

The intuition behind Proposition 4 is that the seller is made a residual claimant. If  $\bar{v} \geq c_h$ , he receives the entire trade surplus minus a constant term,  $(\bar{v} - p)$ . He will therefore have incentives to invest at the socially optimal level. As the high quality threshold also induces the ex-post efficient trade decision the contract achieves the first best.<sup>14</sup>

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<sup>14</sup>If we relax our simplifying assumption by assuming  $v_h \geq c_h$ , one can readily show that a contract that specifies a sufficiently high quality threshold,  $\bar{v} \geq v_h$ , still induces the first best. However, the delivery decision can also be efficient outside the first best. This is for example the case if  $v_h > \bar{v} \geq c_h$ .

As mentioned, we adopted Stremitzer's (2012) assumption that damages in case of non-delivery amount to  $\bar{v} - p$ , which essentially is a cap on expectation damages.

It is debatable whether parties who stipulate a level of required quality for goods in a contract also set a cap on damages.<sup>15</sup> The remedy of expectation damages requires the breaching party to pay an amount such that the victim of breach is as well off as if the contract had been performed. If the quality level that can be delivered is much higher than the quality level required under the contract, the question arises whether expectation damages are calculated with respect to what was required under the contract ( $\bar{v}$ ) or with respect to the higher quality level the seller could have delivered ( $v$ ). In the latter case, damages would amount to the maximum of true quality,  $v$ , and stipulated quality,  $\bar{v}$ , minus price. Luckily we do not need to resolve this question as it can be shown that under either interpretation the result in Proposition 4 would hold. Under the alternative view, the seller's ex-post payoff in case of non-delivery would be  $-\max[v, \bar{v}] - p$  instead of  $-(\bar{v} - p)$ . His ex-post payoff in the situation where he delivers remains the same. Note that if the parties write a Cadillac contract,  $\bar{v} = v_h$ , damages are the same under capped and non-capped expectation damages. Accordingly, the seller's ex-post payoff is the same in both situations which allows us to conclude that his trade decision and therefore also his ex-ante investment incentives coincide. The distinction between capped and non-capped expectation damages, however, crucially affects Proposition 3. As explained above, under capped expectation damages it may happen that the seller's ex-post trade decision is inefficient. Under non-capped expectation damages the seller's decision is efficient: He delivers the good whenever  $p - c - \max[\bar{v} - v, 0] \geq -\max[v, \bar{v}] - p$  or equivalently  $v \geq c$ . Hence, a Cadillac contract induces the first best under capped- and non-capped expectation damages but only in the non-capped case expectation damages keep the efficient breach property.

Our result can also be contrasted to a related result by Edlin (1996) who analyzes the efficiency of expectation damages if investment is *purely selfish*. In the case of a seller, who

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<sup>15</sup>Similarly, when the law requires quality, such as through an implied warranty of merchantability, the question arises whether it is also limiting the amount of damages the buyer may collect in case of non-delivery of the good.

invests in order to lower his variable cost of performance, he finds that a contract which specifies the highest possible quantity (a so-called "Cadillac contract") will make the seller a residual claimant if the contract price is set low enough that it will always be the investing seller who breaches the contract. In order to make the seller accept such a low price, the contract also specifies up-front lump sum payment from the buyer to the seller.<sup>16</sup>

Our result differs in two respects. First, we are concerned with inducing hybrid investments as opposed to purely selfish investments. In other words, the seller's investment not only serves to lower the seller's variable cost of delivery but stochastically determines both the seller's cost and the good's quality (and therefore the buyer's valuation for the good).<sup>17</sup> While first best purely selfish investments could be achieved in our setting through a contract that specifies the highest possible quantity (*one* unit in a binary setting) but is silent about quality, parties need to specify the highest possible quantity *and* the highest possible quality level in order to achieve first best hybrid investments. This is because the value increasing effect of investment can only be internalized through the seller's expected damage payments which arise when quality is non-conforming to the contract. The second major difference to Edlin (1996) is that we do not rely on up-front payments as, in equilibrium, our bilateral breach game leads to the same payoff profile for the investing party as if we assumed that only the seller breached the contract. Parties can therefore use the contract price as an instrument to divide the expected gains from trade.

Finally, note that our first-best result holds even if the seller's expected payoff function,  $U^{ED}(e)$ , is not strictly quasi-concave in  $e$  for all  $\bar{v}$ . To derive results outside the first best, we have to impose stronger assumptions on the seller's expected payoff function.<sup>18</sup> We prove

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<sup>16</sup>Already Shavell (1984) had recognized that expectation damages induce the first best if the investing party is the breaching party. Actually, the results are structurally the same, as Shavell (1984) implicitly assumes that the contract specifies the highest possible quantity by modelling the trade decision as binary (a contract requiring delivery then automatically specifies the "highest" possible quantity). Shavell (1984) did not, however, describe how up-front payments can be used to contractually manipulate the identity of the breaching party.

<sup>17</sup>Edlin also offers an interpretation of his model, where a Cadillac contract would mean that parties stipulate the highest possible *quality*. Yet, in his model, delivering high or low quality is a choice variable of the seller just as delivering high or low quantity. In our setting, quality is stochastically determined by the cooperative component of the seller's ex-ante investment.

<sup>18</sup>We assume that damages are capped. A similar result can be derived for non-capped expectation

the following proposition:

**Proposition 5** (i) *If the contract specifies a low quality level,  $\bar{v} < c_h$ , and  $U^{ED}$  is strictly quasi-concave in  $e$  for all  $\bar{v}$ , the seller underinvests. (ii) *If  $U^{ED}$  is strictly concave in  $e$  for all  $\bar{v}$ , investment incentives rise in the level of required quality.**

Proof: See the Appendix.

Intuitively, underinvestment occurs for two reasons: If the product is conforming to the contract,  $v \geq \bar{v}$ , and the seller decides to deliver, he receives  $p - c$ . If  $v > c > \bar{v}$ , the seller refuses to deliver and pays damages of  $-(\bar{v} - p)$  even though it would be socially optimal to trade. In both cases, he does not take into account the value-increasing effect of his investment. Since both sources of inefficiency diminish as  $\bar{v}$  approaches  $v_h$ , investment incentives increase in the threshold value  $\bar{v}$ . The result extends the proof of Stremitzer (2012) that it is possible to implement the efficient outcome with expectation damages in a setting of purely cooperative investment to the hybrid case.

## 7.2 Expectation damages with renegotiation

When renegotiation is possible, the parties use the payoff they would receive in the absence of renegotiation as a threat point. Consequently, the payoffs in Figure 3 must be adjusted to take into account the effect of renegotiation (see Figure 4).<sup>19</sup>

Recall from Proposition 3 that an optimal contract governed by expectation damages,  $\bar{v} \geq v_h = c_h$ , induces an efficient ex-post delivery decision. Proposition 6 directly follows:

**Proposition 6** *If renegotiations are possible and parties specify a sufficiently high quality threshold,  $\bar{v} \geq v_h$ , expectation damages induce the first best.*

The intuition behind Proposition 6 is that an efficient ex-post delivery decision renders renegotiations worthless. Hence, payoffs in equilibrium are the same as in the no-renegotiation case and the investment incentives coincide. If the parties specify a threshold

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damages.

<sup>19</sup>Note that we assume that  $p \leq \bar{v}$  which allows us to simplify payoffs. Moreover, the payoffs in Figure 4 are given for the capped version of expectation damages only.

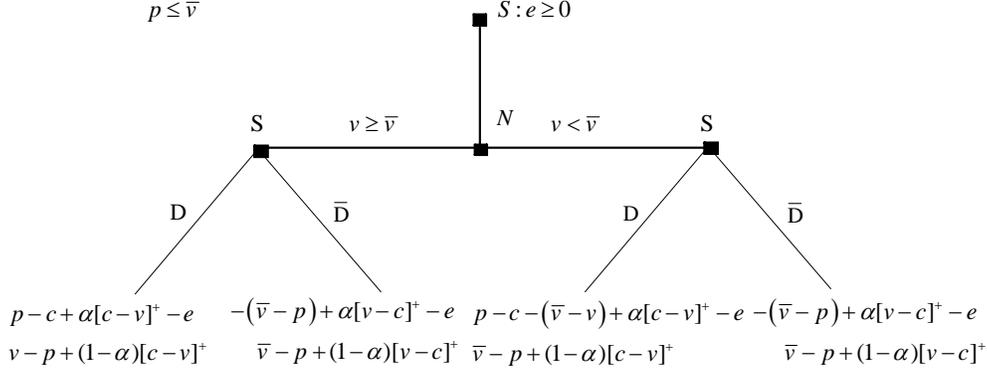


Figure 4: Subgame induced by expectation damages if renegotiation is possible.

below Cadillac level,  $\bar{v} < v_h$ , it is crucial to distinguish between capped- and non-capped expectation damages. Under non-capped expectation damages the delivery decision is always efficient and accordingly there is no scope for renegotiation. Thus, the incentives coincide. Under capped expectation damages, the seller has higher incentives compared to the case without renegotiation. To see this, let us consider the extreme case where  $\bar{v} < c_l$ . Because  $p \leq \bar{v}$ , the seller announces not to deliver whether renegotiation is possible or not. If it is not, his payoff is zero and thus he has no incentive to invest. In contrast, if renegotiation is possible, the seller ex-post receives his share of the renegotiation surplus,  $\alpha[v - c]^+$ . Thus, he invests as if the parties did not write a contract at all. In contrast, we know from Proposition 6 that investment incentives coincide if the contract stipulates a sufficiently high threshold. It is then straightforward to show that the positive impact of renegotiation is decreasing in the level of the quality threshold.<sup>20</sup>

## 8 Conclusion

It is reassuring that expectation damages, the default remedy of common law, not only performs well in a setting of purely cooperative investments but also in the hybrid case. Indeed, the same Cadillac contract which achieves the first best in the purely cooperative

<sup>20</sup>Stremitzer (2012) proves this in a setting of purely cooperative investment. The proof for hybrid investment is very similar and available upon request.

setting also achieves the first best in the hybrid case. On the other hand, under liquidated damages and reliance damages, parties must fine-tune the terms of contract, stipulate up-front payments, and rely on renegotiation to achieve the first best. Even then, they may not achieve the first best when investments are of a hybrid nature. Our analysis therefore suggests that parties should think twice before opting out of default expectation damages for privately stipulated reliance damages, in contrast to the recommendation of Che and Chung (1999). A more troubling result regarding expectation damages is that efficient ex-post trade may only be guaranteed if parties set the quality threshold sufficiently high. Otherwise, as under liquidated damages and reliance damages, there are states of the world where parties must rely on renegotiation to achieve the ex-post efficient allocation.

So far, the literature on the incentive effects of different breach remedies has mainly focused on comparing the efficiency of different remedies such as expectation damages, reliance damages or specific performance in varying environments. Yet, even though these settings are usually quite specific, parts of the literature make broader claims to the effect that a certain breach remedy performs well/poorly in general. For instance, Plambeck and Taylor (2007) state that the specific performance remedy is more efficient than expectation damages for inducing optimal relationship-specific investment. They consider a model where  $N$  buyers make a selfish investment (innovation) whereas the seller invests to increase capacity such that he or she can supply higher quantities to the buyers after the outcome of the innovation is realized. Since their model is essentially building on Edlin and Reichelstein's (1996) model of bilateral selfish investment, they find in accordance with Edlin and Reichelstein, that expectation damages perform poorly in a setting of bilateral selfish investment. However, as Ohlendorf (2009) has pointed out, expectation damages induce efficient bilateral investment if the cost function is not linear, as in Edlin and Reichelstein (1996), but sufficiently concave.<sup>21</sup> This, together with the result of our present paper, suggests that properly specified

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<sup>21</sup>Plambeck and Taylor (2007) actually find that the first best is attainable under bilateral expectation damages if the parties can affect their ex-post bargaining power through renegotiation design. However Ohlendorf's (2009) finding suggests that renegotiation design is not necessary to induce efficient bilateral investment under expectation damages.

expectation damages perform well almost any situation where sufficient information is available to assess them. The main role for alternative regimes such as specific performance or reliance damages therefore is to offer alternative solutions for situations where informational constraints render them easier to assess than expectation damages.

Finally, our analysis illustrates a subtle difference between mechanism design and the economic analysis of real world institutions. As we have already mentioned, the enforcement of reliance damages requires investment to be verifiable. Thus parties should theoretically be able to achieve the first best by writing a forcing contract in which they stipulate the efficient investment level. Yet, we show that this does not necessarily imply that reliance damages induce the first best. Indeed, the issue is not whether the information required to operate an institution is in theory sufficient to achieve the first best. It is about how institutions make use of that information.<sup>22</sup>

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<sup>22</sup>Both Che and Chung (1999) and Schweizer (2006) prove interesting results, although, by requiring investment to be verifiable, their insights are not surprising from the perspective of contract theory.

## 9 Appendix

### 9.1 Proof of Proposition 1

**Proof.** To prove Proposition 1, it is sufficient to construct an example where the seller overinvests regardless of price. Here, we consider the simple case where the seller's bargaining power is very small,  $\alpha \rightarrow 0$ .<sup>23</sup> The proof comes in three steps. (i) We derive the investment level that maximizes the seller's expected payoff. (ii) Let  $e^{\overline{RD}}$  be the investment level that maximizes the seller's expected payoff for  $p = 0$ . We can then derive a condition for which  $e^{\overline{RD}}$  is higher than the social optimal level,  $e^*$ . (iii) We show that the seller never invests less than  $e^{\overline{RD}}$  if the contract specifies a positive price. If the condition that is given in the second part of the proof holds, it then directly follows that the seller overinvests regardless of price.

(i) Anticipating the buyer's decision at date 3, the seller, at date 1, expects to receive the following payoff:

$$U^{RD}(e) = \int_{c_l}^{c_h} \int_0^{\hat{v}^{RD}} (e + \alpha[v - c]^+) F_v(v|e) dv G_c(c|e) dc + \int_{c_l}^{c_h} \int_{\hat{v}^{RD}}^{v_h} (p - c + \alpha[c - v]^+) F_v(v|e) dv G_c(c|e) dc - e. \quad (10)$$

We assume that  $U^{RD}(e)$  is strictly quasi-concave in  $e$  for all  $p$  to ensure that there exists a unique equilibrium investment level. Let  $\tilde{v}^{RD} \equiv \frac{p-e-c_h}{\alpha} + c_h$  and  $\hat{c}^{RD} \equiv \frac{p-e-\alpha v_h}{1-\alpha}$  where  $\hat{c}^{RD}$  is defined such that  $c \leq \hat{c}^{RD}$  implies  $\hat{v}^{RD} = v_h$  and  $c \geq \hat{c}^{RD}$  implies  $\hat{v}^{RD} = \frac{p-e-c}{\alpha} + c$  (see expression 4). Twice integrating by parts and reorganizing, we can rewrite (10) as follows:<sup>24</sup>

$$U^{RD}(e) = p - e - c_h + \alpha \int_{\tilde{v}^{RD}}^{v_h} F(v|e) + \int_{c_l}^{c_h} G(c|e) dc - \alpha \int_{c_l}^{c_h} F(c|e) G(c|e) dc - (1 - \alpha) \int_{\hat{c}^{RD}}^{c_h} F(\hat{v}^{RD}|e) G(c|e) dc - (1 - \alpha) \int_{c_l}^{\hat{c}^{RD}} G(c|e) dc. \quad (11)$$

<sup>23</sup>It is not necessary that the seller's bargaining power is marginal, as in our example, to prove that overreliance can occur. However this example allows for a relatively simple intuition compared to cases of larger bargaining powers.

<sup>24</sup>Omitted intermediate steps are available upon request.

Hence, the investment level  $e^{RD}$  that maximizes the seller's expected payoff is given by the following first-order condition:

$$\begin{aligned}
U'^{RD}(e^{RD}) &= F(\tilde{v}^{RD}|e^{RD}) + \alpha \int_{\tilde{v}^{RD}}^{v_h} F_e(v|e^{RD}) dv + \int_{c_l}^{c_h} G_e(c|e^{RD}) dc & (12) \\
&- \alpha \int_{c_l}^{c_h} [F_e(c|e^{RD})G(c|e^{RD}) + F(c|e^{RD})G_e(c|e^{RD})] dc \\
&- (1 - \alpha) \int_{\hat{c}^{RD}}^{c_h} [F_e(\hat{v}^{RD}|e^{RD}) - \frac{1}{\alpha}F_v(\hat{v}^{RD}|e^{RD})] G(c|e^{RD}) dc \\
&- (1 - \alpha) \int_{\hat{c}^{RD}}^{c_h} F(\hat{v}^{RD}|e^{RD})G_e(c|e^{RD}) dc + [1 - F(\hat{v}^{RD}|e^{RD})]G(\hat{c}^{RD}|e^{RD}) \\
&- (1 - \alpha) \int_{c_l}^{\hat{c}^{RD}} G_e(c|e^{RD}) dc - 1 = 0.
\end{aligned}$$

(ii) To show that overinvestment relative to the socially optimal level can arise for  $p = 0$ , consider the case where the seller's bargaining power is very small,  $\alpha \rightarrow 0$ . Inserting  $p = 0$  into (12) yields:

$$\begin{aligned}
U'^{RD}(e^{\overline{RD}}) &= \alpha \int_{\tilde{v}^{RD}}^{v_h} F_e(v|e^{\overline{RD}}) dv + \int_{c_l}^{c_h} G_e(c|e^{\overline{RD}}) dc & (13) \\
&- \alpha \int_{c_l}^{c_h} [F_e(c|e^{\overline{RD}})G(c|e^{\overline{RD}}) + F(c|e^{\overline{RD}})G_e(c|e^{\overline{RD}})] dc - 1 = 0
\end{aligned}$$

and the limit as  $\alpha$  goes to zero is given by:

$$\lim_{\alpha \rightarrow 0} U'^{RD}(e^{\overline{RD}}) = \int_{c_l}^{c_h} G_e(c|e^{\overline{RD}}) dc - 1 = 0.$$

It is clear that  $e^{\overline{RD}} > e^*$  if the first derivative of the expected social welfare function (2) evaluated at  $e^{\overline{RD}}$  is negative.<sup>25</sup>

$$\begin{aligned}
W'(e^{\overline{RD}}) &= \int_{c_l}^{c_h} ([1 - F(c|e^{\overline{RD}})]G_e(c|e^{\overline{RD}}) - F_e(c|e^{\overline{RD}})G(c|e^{\overline{RD}})) dc - 1 < 0 & (14) \\
&\iff + \int_{c_l}^{c_h} [-F(c|e^{\overline{RD}})G_e(c|e^{\overline{RD}}) - F_e(c|e^{\overline{RD}})G(c|e^{\overline{RD}})] dc < 0.
\end{aligned}$$

This is indeed the case for those parameter constellations where the first negative term in the second line of (14) is larger in absolute value than the second, positive, term or where

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<sup>25</sup>Strict quasi-concavity of  $W(e)$  in  $e$  ensures that  $W(e)$  is single peaked and therefore  $W'(e^{\overline{RD}}) < 0$  implies  $e^{\overline{RD}} > e^*$ .

the selfish effect of investment is strong relative to the cooperative effect,  $G_e(c|e^{\overline{RD}}) \gg -F_e(c|e^{\overline{RD}})$ .

(iii) We have already shown that the seller overinvests relative to the socially optimal level if  $p = 0$  has been specified in contract and condition (14) holds. We now show that the seller will not invest less than  $e^{\overline{RD}}$ , if a positive price has been specified in contract. Consider the limit of (12) as  $\alpha$  goes to zero:

$$\begin{aligned} \lim_{\alpha \rightarrow 0} U'^{RD}(e^{RD}) &= F(\tilde{v}^{RD}|e^{RD}) + \int_{c_l}^{c_h} G_e(c|e^{RD}) dc \\ &\quad - \int_{\hat{c}^{RD}}^{c_h} [F_e(\hat{v}^{RD}|e^{RD}) - \infty F_v(\hat{v}^{RD}|e^{RD})] G(c|e^{RD}) dc \\ &\quad - \int_{\hat{c}^{RD}}^{c_h} F(\hat{v}^{RD}|e^{RD}) G_e(c|e^{RD}) dc + [1 - F(\hat{v}^{RD}|e^{RD})] G(\hat{c}^{RD}|e^{RD}) \\ &\quad - \int_{c_l}^{\hat{c}^{RD}} G_e(c|e^{RD}) dc - 1 = 0. \end{aligned} \tag{15}$$

Fixing  $e = e^{\overline{RD}}$  and considering  $U'^{RD}$  as a function of  $p$ , the seller will invest at least  $e^{\overline{RD}}$  if  $U'^{RD}(p) \geq 0$  for all  $p > 0$ .<sup>26</sup> After reorganizing,  $U'^{RD}(p) \geq 0$  for all  $p > 0$  is equivalent to the following condition:

$$\begin{aligned} \lim_{\alpha \rightarrow 0} U'^{RD}(p) &= F(\tilde{v}^{RD}|e^{\overline{RD}}) + [1 - F(\hat{v}^{RD}|e^{\overline{RD}})] G(\hat{c}^{RD}|e^{\overline{RD}}) \\ &\quad - \int_{\hat{c}^{RD}}^{c_h} [F_e(\hat{v}^{RD}|e^{\overline{RD}}) - \infty F_v(\hat{v}^{RD}|e^{\overline{RD}})] G(c|e^{\overline{RD}}) dc \\ &\quad + \int_{\hat{c}^{RD}}^{c_h} [1 - F(\hat{v}^{RD}|e^{\overline{RD}})] G_e(c|e^{\overline{RD}}) dc \geq 1 \quad \forall p > 0. \end{aligned} \tag{16}$$

Recall that  $c \geq \hat{c}^{RD}$  implies  $\hat{v}^{RD} = \frac{p-e-c}{\alpha} + c \leq v_h$ . Then, the term in the second line makes sure that condition (16) holds unless  $\hat{v}^{RD} \leq 0$  or  $\hat{c}^{RD} \geq c_h$  for all  $c$ . In the latter two cases, the term in the second line is equal to zero. Hence, what is left is to show is that condition (16) holds if  $\hat{v}^{RD} \leq 0$  or  $\hat{c}^{RD} \geq c_h$ . First, since  $\hat{v}^{RD} \leq 0$  must hold for all  $c$  it must in particular hold for  $c = c_l$ . This implies that

$$\frac{p - e^{\overline{RD}} - c_l}{\alpha} + c_l \leq 0 \Leftrightarrow c_l \geq \frac{p - e^{\overline{RD}}}{(1 - \alpha)}. \tag{17}$$

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<sup>26</sup> Strict quasi-concavity of  $U'^{RD}$  in  $e$  for all  $p$  ensures that  $U'^{RD}$  is single peaked. Then  $U'^{RD}(p) \geq 0$  ensures that the seller invests at least  $e = e^{\overline{RD}}$  for a given  $p$ .

Now since  $p - e^{\overline{RD}} > p - e^{\overline{RD}} - \alpha v_h$ , we can conclude that

$$c_l = \frac{p - e^{\overline{RD}}}{(1 - \alpha)} > \frac{p - e^{\overline{RD}} - \alpha v_h}{(1 - \alpha)} \equiv \hat{c}^{RD}. \quad (18)$$

Then the last term of (16) is equal to 1 and because the other terms are all nonnegative, condition (16) must hold. The last step is to prove that condition (16) holds if  $\hat{c}^{RD} \geq c_h$ . This case directly implies that

$$p \geq e^{\overline{RD}} + c_h. \quad (19)$$

But if (19) holds,  $F(\tilde{v}^{RD} | e^{\overline{RD}}) = 1$  must be true. Then again, because all other terms are nonnegative, condition (16) must hold. Hence condition (16) holds for all  $p > 0$  and we have shown that the seller will invest at least  $e^{\overline{RD}}$  if  $p > 0$  has been specified in the contract. Since  $e^{\overline{RD}} > e^*$ , the seller will overinvest relative to the socially efficient level for any price.

■

## 9.2 Proof of Proposition 2

To prove that the first best is attainable if investment is sufficiently selfish, we first (i) derive the seller's expected payoff function and the corresponding first order condition that represents his optimal investment level. (ii) We then consider the situation where the parties have specified a sufficiently high  $p - \delta$  such that it is ex-ante known that the buyer will ex-post refuse to accept the good. In that case, the seller underinvests. (iii) Finally, we consider that  $p - \delta$  is sufficiently low such that it is ex-ante known that the buyer will ex-post announce to accept the good. We demonstrate that the seller overinvests if investment is sufficiently selfish. Because investment depends continuously on  $p - \delta$ , there then exists some intermediate  $p - \delta$  that induces first-best investment.

(i) We explained in the main text that the buyer announces breach if

$$-\delta + (1 - \alpha)[v - c]^+ > v - p + (1 - \alpha)[c - v]^+ \quad (20)$$

or equivalently if

$$v < \hat{v}^{LD} \equiv \min \left[ \frac{p - \delta - c}{\alpha} + c, v_h \right]. \quad (21)$$

Anticipating the buyer's decision, the seller expects to receive, at date 1, the following payoff:

$$\begin{aligned}
U^{LD}(e) &= \int_{c_l}^{c_h} \int_0^{\hat{v}^{LD}} (\delta + \alpha[v - c]^+) F_v(v|e) dv G_c(c|e) dc \\
&\quad + \int_{c_l}^{c_h} \int_{\hat{v}^{LD}}^{v_h} (p - c + \alpha[c - v]^+) F_v(v|e) dv G_c(c|e) dc - e.
\end{aligned} \tag{22}$$

We assume that  $U^{LD}(e)$  is strictly quasi-concave in  $e$  for all  $p - \delta$  to ensure that there exists a unique equilibrium investment level. Twice integrating by parts and reorganizing we can rewrite (22) as follows:<sup>27</sup>

$$\begin{aligned}
U^{LD}(e) &= p - \delta - c_h + \alpha \int_{\hat{v}^{LD}}^{v_h} F(v|e) + \int_{c_l}^{c_h} G(c|e) dc \\
&\quad - \alpha \int_{c_l}^{c_h} F(c|e)G(c|e) dc - (1 - \alpha) \int_{c_l}^{c_h} F(\hat{v}^{LD}|e)G(c|e) dc - e.
\end{aligned} \tag{23}$$

Hence, the investment level  $e^{LD}$  that maximizes the seller's expected payoff is given by the following first-order condition:

$$\begin{aligned}
U'^{LD}(e^{LD}) &= \alpha \int_{\hat{v}^{LD}}^{v_h} F_e(v|e^{LD}) dv + \int_{c_l}^{c_h} G_e(c|e^{LD}) dc \\
&\quad - \alpha \int_{c_l}^{c_h} [F_e(c|e^{LD})G(c|e^{LD}) + F(c|e^{LD})G_e(c|e^{LD})] dc \\
&\quad - (1 - \alpha) \int_{c_l}^{c_h} [F_e(\hat{v}^{LD}|e^{LD}) G(c|e^{LD}) - F(\hat{v}^{LD}|e^{LD})G_e(c|e^{LD})] dc - 1 = 0.
\end{aligned} \tag{24}$$

(ii) Fixing  $e = e^*$  and considering  $U'^{LD}$  as a function of  $p - \delta$ , we first consider the situation where  $p - \delta$  is sufficiently high such that the buyer always announces breach ex-post. This is the case if  $p - \delta > \alpha v_h + (1 - \alpha)c_h$ . The seller invests less than the socially optimal level,  $e^*$ , if  $U'^{LD}(p - \delta) < 0$  for all  $p - \delta > \alpha v_h + (1 - \alpha)c_h$ .<sup>28</sup> Considering (24) as a function of  $p - \delta$ , we get for any  $p - \delta > \alpha v_h + (1 - \alpha)c_h$ :

$$U'^{LD}(p - \delta) = \alpha \int_{c_l}^{c_h} [1 - F(c|e^*)]G_e(c|e^*) - F_e(c|e^*)G(c|e^*)] dc - 1 < 0. \tag{25}$$

Using the benchmark (2) we can rewrite (25):

$$-(1 - \alpha) \int_{c_l}^{c_h} [1 - F(c|e^*)]G_e(c|e^*) - F_e(c|e^*)G(c|e^*)] dc < 0. \tag{26}$$

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<sup>27</sup>Omitted intermediate steps are available upon request. In case of liquidated damages,  $\hat{v}^{LD} \equiv \frac{p - \delta - c_h}{\alpha} + c_h$  and  $\hat{c}^{LD} \equiv \frac{p - \delta - \alpha v_h}{1 - \alpha}$

<sup>28</sup>Strict quasi-concavity of  $U^{LD}$  in  $e$  for all  $p - \delta$  ensures that  $U^{LD}$  is single peaked. Thus  $U'^{LD}(p - \delta) < 0$  implies that the seller invests less than  $e = e^*$  for any  $p - \delta > \alpha v_h + (1 - \alpha)c_h$ .

Due to Assumptions 2 and 3, the left-hand side of (26) is negative. Thus, the seller underinvests unless he has the entire bargaining power.

(iii) Fixing  $e = e^*$ , we again consider  $U^{ILD}$  as a function of  $p - \delta$ . Suppose  $p - \delta = 0$ . The seller invests at least  $e^*$  if  $U^{ILD}(0) \geq 0$ . Considering 24 as a function of  $p - \delta$  and inserting  $p - \delta = 0$  yields:

$$U^{ILD}(0) = \alpha \int_0^{v_h} F_e(v|e^*) dv + \alpha \int_{c_l}^{c_h} [1 - F(c|e^*)]G_e(c|e^*) - F_e(c|e^*)G(c|e^*)] dc \quad (27)$$

$$+ (1 - \alpha) \int_{c_l}^{c_h} G_e(c|e^*) dc - 1 \geq 0.$$

Using the benchmark (2) we can rewrite (27):

$$U^{ILD}(0) = \alpha \int_0^{v_h} F_e(v|e^*) dv + (1 - \alpha) \int_{c_l}^{c_h} [F(c|e^*)G_e(c|e^*) + F_e(c|e^*)G(c|e^*)] dc \geq 0 \quad (28)$$

or equivalently

$$(1 - \alpha) \int_{c_l}^{c_h} F(c|e^*)G_e(c|e^*) dc \geq -(1 - \alpha) \int_{c_l}^{c_h} F_e(c|e^*)G(c|e^*) dc - \alpha \int_0^{v_h} F_e(v|e^*) dv. \quad (29)$$

The terms on both sides of (29) are positive. If the cooperative effect of investment is small, thus if  $F_e(\cdot|e^*)$  is small, the seller overinvests. In this situation, because investment depends continuously on  $p - \delta$ , there exists some intermediate  $p - \delta$  that induces first-best investment. If investment is sufficiently close to purely cooperative investment, it directly follows from Che and Chung (1999) that the first best is unattainable because the seller underinvests relative to the socially optimal level.

### 9.3 Proof of Proposition 5

**Proof.** (i) To see that underinvestment will be the norm recall that  $U^{ED}(e^*) = 0$  if  $\bar{v} = c_h$ . Fixing  $e = e^*$ , we consider  $U^{ED}(\cdot)$  as a function of  $\bar{v}$ . The seller has lower investment incentives relative to the socially optimal level if  $U^{ED}(\bar{v}) < 0$  for all  $\bar{v} < c_h$ .<sup>29</sup> This is true

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<sup>29</sup>Strict quasi-concavity of  $U^{ED}$  in  $e$  for all  $\bar{v}$  ensures that  $U^{ED}$  is single peaked and hence the following argument is valid. Note that strict quasi-concavity is a common assumption to ensure a unique equilibrium level.

because, for all  $\bar{v} < c_h$

$$\begin{aligned}
U^{ED}(\bar{v}) &= \int_{c_l}^{\bar{v}} ([1 - F(c|e^*)] G_e(c|e^*) - F_e(c|e^*) G(c|e^*)) dc - 1 & (30) \\
&= \int_{c_l}^{c_h} ([1 - F(c|e^*)] G_e(c|e^*) - F_e(c|e^*) G(c|e^*)) dc - 1 \\
&\quad - \int_{\bar{v}}^{c_h} ([1 - F(c|e^*)] G_e(c|e^*) - F_e(c|e^*) G(c|e^*)) dc < 0.
\end{aligned}$$

Note that the term in the second line of (30) is equal to zero whereas the term in the third line must be negative by assumptions 2 and 3.

(ii) If  $U^{ED}(e)$  is strictly concave in  $e$  for all  $\bar{v}$ , investment incentives rise in the level of required quality. To see this, note that investment incentives rise in the threshold if  $\frac{de^{ED}}{d\bar{v}} > 0$ . Implicitly differentiating 9 and rearranging, we have:

$$\frac{de^{ED}}{d\bar{v}} = - \frac{\{[1 - F(\bar{v}|e^{ED})]G_e(\bar{v}|e^{ED}) - F_e(\bar{v}|e^{ED})G(\bar{v}|e^{ED})\} dc}{\int_{c_l}^{\bar{v}} \{[1 - F(c|e)]G_{ee}(c|e) - F_{ee}(c|e)G(c|e) - 2F_e(c|e)G_e(c|e)\} dc}. \quad (31)$$

The numerator of (31) must be positive due to assumptions 2 and 3. Strict concavity implies that the denominator of (31) must be negative because it is equivalent to  $U''^{ED}$ . Hence we can conclude that  $\frac{de^{ED}}{d\bar{v}} > 0$ . ■

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