Courts’ Decisions, Cooperative Investments, and Incomplete Contracts

Alessandro De Chiara∗

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Abstract

Buyers are often concerned about the adequateness of the design of the goods they procure. To reduce the probability of a failure, buyers may try to motivate their sellers to invest so as to improve the design. In this paper I study how courts’ decisions affect sellers’ cooperative investment and buyers’ specification of the good. In assigning liability for a defective design, courts consider how much real authority the seller had in performing the work and therefore disregard how formal authority was contractually allocated between the parties. I show that this approach induces the sellers to invest, albeit suboptimally, but leads the buyers to inefficiently under-specify the terms of the contract. I explore potential remedies, including different legal regimes and relational contracting.

Keywords: Cooperative Investments, Courts, Defective Specifications, Expectation Damages, Formal and Real Authority, Incomplete Contracts.

JEL classifications: D23; D86, K12, L23, L24.

1 Introduction

Buyers devote significant resources to planning and designing sophisticated goods, such as buildings or dams, as they are aware of the disastrous consequences of a design failure.1 Moreover, buyers often rely on the sellers’ expertise and know-how to improve upon the design during production and make sure that the good performs as expected. The seller’s involvement is costly though and may take the form of a relationship-specific investment, since it must meet the buyer’s unique needs. As a result, when the investment cannot be contracted upon, the seller may be willing to dedicate less resources than it would be efficient, as argued by Williamson (1985). This is so especially in the case when the investment is cooperative, in the sense that it generates a direct benefit to the trading party (see Che and Hausch, 1999).

To motivate the cooperative investment, a buyer may delegate the responsibility for the soundness of the design to the seller. Indeed, unlike the investment, a court may be able to verify a design failure. However, even if the seller is contractually made responsible for the design, the buyer may not be wholly immune from liability. Quite surprisingly, in the U.S. the

∗Central European University; dechiaraa@ceu.edu.

1One notable example of the consequences of a poorly planned project is the Big Dig in Boston. See “10 years later, did the Big Dig deliver?” on Boston Globe, December 29, 2015.
typical approach followed by courts to determine liability for a defective design is to consider how much latitude the seller was given in performing the work. Namely, following the popular Aghion and Tirole’s distinction between formal and real authority (see Aghion and Tirole, 1997), existing case-law shows that courts typically disregard how formal authority over the soundness of the design had been allocated between the parties. Rather, courts carefully evaluate how much real authority each contracting party ultimately had over the portion of the design which turned out to be defective.2

The objective of this paper is to study how courts’ decisions affect sellers’ cooperative investment and buyers’ specification of the good. To my knowledge, this is the first article in the economics literature that analyzes how buyers’ and sellers’ incentives and behavior are affected by the approach followed by courts when the design is defective. My focus is on breach remedies. In particular, I assume that the court follows the expectation damages rule to assess damages for a design failure. The expectation damages rule is the default remedy and its intent is to put the harmed party in the same position he or she would have been had the contract been performed.

In the model, prior to contracting with a seller, a buyer decides how much to specify the characteristics of the good she wants to procure. Specification is costly and increases the likelihood that the design of the good will be adequate. I interpret this costly specification as an investment in the completeness of the contract. As a result, the contract is said to be more complete when the cost incurred by the buyer to specify the good is higher. At the contracting stage the parties agree on the price and, during production, the seller decides how much to invest to improve the quality of the design, which further decreases the probability of a failure. Both the buyer’s specification and the seller’s cooperative investment are assumed to be observable but not verifiable. Only when the good is produced, do the parties learn whether or not the design is correct. If the design fails, the buyer may sue the seller and the court certifies that the design is defective and attaches liability to either party.

The expectation damages rule can prompt the seller to invest so as to avoid being compelled by a court to pay the buyer the damages due to a defective design. However, consistently with the approach adopted by courts, the probability that the seller will be held liable for defects in the design is decreasing in the buyer’s specification of the good. Therefore, with a higher level of contract completeness the buyer reduces the likelihood of a design failure but, at the same time, increases the chances that, if there is a defect, this will be associated with some characteristic of the good that she initially specified.

The paper finds that the ability of courts to attach liability for a design failure has an upside and a downside. The former is that it motivates the seller to invest, even though investment is less than first-best. The latter is that it induces the buyer to under-specify the good. This is shown by also considering an environment in which courts cannot assign liability in the presence of defects of design. There the seller has no incentive to invest, and the buyer optimally specifies the characteristics of the good.

I also study whether alternative rules to assign liability for a defective design and different methods to determine damages can alleviate the under-investment and under-specification prob-

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2The courts’ approach to assign liability is extensively described in Section 2.1.
lems. I find that both inefficiencies are mitigated if courts employ the expectation damages rule but allocate liability according to how formal authority has been allocated between the parties. In addition, I show that the first-best seller’s investment can be achieved under the liquidated damages rule. With this rule, that courts are often reluctant to follow, the victim of breach is awarded a predetermined amount of money that the contracting parties mutually agreed upon.

Furthermore, I also analyze how, in the presence of repeated interaction, the buyer and the seller may be able to use relational incentives to achieve the efficient level of investment and the optimal specification of the good. Contrary to previous results (e.g., Tirole, 2009), I highlight how relational contracting may reduce and not generate contract incompleteness.

The paper is organized as follows. Section 2 discusses the relevant law cases which shed light on the approach followed by courts to determine liability for design failures and relates the paper to the literature. Section 3 introduces the model and Section 4 presents the main analysis. Section 5 presents some potential remedies to the under-investment and under-specification problems. Section 6 shows that the main results of the paper are robust to the presence of substitutability or complementarity between contractual specification and cooperative investment. Section 7 provides some concluding remarks.

2 Case-Law and Related Literature

In this section, I first illustrate the relevant case-law on defective specifications and then I review the literature most closely related to the present paper.

2.1 Case-Law Associated with Defective Specifications

An examination of the existing case-law associated with defective good specifications sheds light on why buyers are not always able to make the sellers accountable for the accuracy of the design. In the United States, an impressive number of legal cases show that a formal delegation of the design task to the seller does not make the buyer immune from liability. Lots of cases arise out of problems occurring in construction projects, although some can also be found in other industries, such as research and development, and product sales.3

One of the most important construction law cases in the United States is United States v. Spearin4 which established that a seller who followed the plans and specifications provided by a buyer could not be held responsible for consequences of defects.5 This is what is now commonly known as the doctrine of implied warranties. As subsequent cases have clarified, the warranty only applies to “design specifications” in which the buyer provides the seller with a detailed road map from which he cannot deviate, whereas the warranty does not attach in the case of “performance specifications” wherein the buyer solely describes the objective to be achieved.6

3An interesting and extensive analysis of these legal cases is provided by Loulakis (2013).
4248 U.S. 132, 39 S. Ct. 59, 63 L. Ed. 166 (1918).
5Although we continue to adhere to the terms buyer and seller, in the building sector and in most of these legal cases they are commonly referred to as the owner and the contractor, respectively.
6This general distinction between the two types of specifications is made in the seminal J.L. Simmons Co. v. United States, 188 Ct. Cl. 684, 412 F.2d 1360, 1362 (1969). Other cases have made clear that “design
In practice, the distinction between design and performance specifications is not always clear and contracts contain both method or design requirements and performance elements, and are often referred to as “composite/mixed specifications”. As noted by the court in the case Utility Contractors Inc. v. United States: 7

The court has difficulty in believing that every government contract entered into can so neatly be placed in such black and white terms as design specification or performance contract. The court does not necessarily find that these terms have to be so mutually exclusive. Certainly one can find numerous government contracts exhibiting both performance and design specifications characteristics.

The approach that courts tend to follow to determine liability for a defective specification is to evaluate how much discretion the contract leaves to the seller in performing the work. Therefore, even if the buyer’s specification mostly contains design elements, the seller may still be held accountable for damages. This occurs if the problems cannot ultimately be ascribed to a flawed design specification furnished by the buyer. For instance, in Utility Contractors Inc. v. United States, although the court acknowledged that the contract was mostly a design specification, it held the seller responsible for the precompletion damages that had occurred due to heavy rainstorms. This was because the government had not impliedly warranted that such damages would have been avoided by following its design. Likewise, when the buyer uses a performance specification, she is not immune from liability if her requirements limit the seller’s discretion and cause damages. For instance, consider Martin Construction Inc. v. United States 8, which involved a seller who was defaulted due to delays in completing a marina. The court lifted the termination, holding that the buyer had contractually required the use of some specific material which had caused a number of changes and the ensuing delay.

The same argument applies to the various project-delivery systems, included the Design-Build where, as opposed to Design-Bid-Build, the builder (i.e. the seller) also provides the design of the project. Although Design-Build is often considered as a way to shift liability for defects from the buyer to the seller, if the seller reasonably relies upon the specification provided by the buyer, he will not be held accountable for flaws in the design. The seminal case in this area is M.A. Mortenson Co. 9 where the final design was similar to that shown in the solicitation documents and was approved by the buyer. The Armed Services Board of Contract Appeals (ASBCA) held that the buyer had impliedly warranted the technical information provided in the drawings and the seller had reasonably relied on their adequacy. 10 At the same time, the seller is not allowed to ignore the prescriptive elements of a performance specification, even if he

7 8 Cl. Ct. 42 (1985).
8 102 Fed. Cl. 562 (2011)
9 ASBCA No. 39978, 1993-3 BCA 26,189.
10 Similarly, in Trataros Construction, Inc. v. General Services Administration (GSBCA No. 14875, 2001-1
is a design-builder, due to the court’s conclusion in *Blake Construction Co. v. United States*.11

There, the court rejected the seller’s argument that he had decided not to follow closely the buyer’s drawings because they had been characterized as diagrammatic.

Most of the case-law presented here concerns the United States. However, also in other countries courts tend to take into account the seller’s discretion and the buyer’s specification to determine who must be held accountable in the case of a design failure. In Italy, articles 1666-1669 of the Civil Code place the responsibility for defects of the project and dissimilarities from the specification requested by the buyer onto the builder (i.e., the seller), unless he manages to prove that the buyer is in fact accountable. In addition, the Supreme Court of Cassation has held that when the buyer interferes with or exerts an extensive control over the choices concerning the preparation and the execution of the project, the buyer and the seller share responsibility towards third parties.12

2.2 Related Literature

The paper contributes to the literature on the effects of different breach remedies on trade and investment decisions, which started with the seminal papers by Shavell (1980), Shavell (1984), and Rogerson (1984). With a selfish investment, i.e., an investment which only benefits the investor (e.g. a seller’s investment that reduces his cost of production), this literature shows that specific performance is weakly superior to expectation damages, which in turn is at least weakly better than reliance damages (see Edlin and Reichelstein, 1996, and Ohlendorf, 2009).

Within this tradition, the present paper is closer to the work by Che and Chung (1999). When the investment is cooperative, in that it generates a direct benefit to the trading party (e.g. a seller’s investment that increases the buyer’s benefit from the procured good), Che and Chung (1999) find that reliance damages perform better than expectation damages. This is because the former serve as direct investment subsidy, e.g. if the buyer refuses to trade, she must reimburse the seller of the investment cost. Stremitzer (2010) augments this setting by assuming that the parties can contract upon a quality threshold and shows that the expectation damages rule induces the first-best investment when renegotiation is possible.13 When the contract can specify investment, Schweizer (2006) establishes that bilateral expectation damages, whereby damages can be claimed if trade is refused or there is under-investment, achieve first best. In these papers, uncertainty resolves after the seller’s investment but before the production cost is borne. Before production takes place the harmed party can sue the seller and renegotiation, when allowed, occurs in the shadow of the law. Moreover, their main aim is to determine which

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111987 F.2d 743, United States Court of Appeals, Federal Circuit 1993.
12See Corte di Cassazione Civile no. 2977, 20/3/98 and no. 467, 13/01/2014.
13The paper also considers an alternative arrangement which combines specific performance and restitution, namely the buyer can decide to give back the good if it falls short of the quality threshold. This regime also motivates investment, since the seller can increase the chances of exceeding the quality threshold and getting the price. The advantages of such regime lie in the reduced informational burden for the courts who should solely certify whether the good matches some agreed-upon requirements.
rule for assessing damages for a breach of contract is the most efficient. In contrast, I consider a setting in which the cost of production has already been borne and the buyer must decide whether or not to sue the seller for a breach of contract when the design of the good delivered is defective. The bulk of my analysis concerns expectation damages and focuses on how the approach followed by courts to assign liability impacts on trading parties’ relationship-specific investments.

The paper is also linked to the literature on efficient contracting to overcome the hold-up problem shown by Hart and Moore (1988) when investments are observable but not verifiable. As shown by Chung (1991) and Aghion et al. (1994), efficient investment can be achieved by adequately specifying the default option if courts enforce specific performance. Within this strand of the literature, Che and Hausch (1999) show that efficiency cannot be achieved when the parties cannot commit not to renegotiate the contractual terms and the investments are cooperative. 14

In assuming that the buyer can costly specify the characteristics of the good so as to reduce the likelihood of an ex-post design failure, I draw on the paper by Bajari and Tadelis (2001). In their setting, the seller cannot make a cooperative investment which improves the design of the good and there is renegotiation to implement the required changes if the design is not adequate. They highlight the benefits of a low-powered incentive scheme, a cost-plus contract, whose flexibility is fruitful when the procured good is complex so that there is a high likelihood of renegotiating the initial agreement. In contrast, I focus on how courts’ decisions concerning liability for defective specification affect the seller’s incentive to invest and the buyer’s incentive to specify the design. The idea of Bajari and Tadelis (2001) that the buyer makes an investment into planning has since then been adopted by other authors, such as Gauza (2007), Chakravarty and MacLeod (2009), and Tirole (2009). In particular, Tirole (2009) develops this concept further and provides the alternative interpretation of an investment in the completeness of the contract, to which I also adhere. Akin to Tirole (2009), I assume that both contracting parties can make specific investments to reduce the probability that the design is not correct. However, I mostly focus on the impact of courts' ruling on investment incentives, whereas Tirole (2009) is concerned with the disclosure of the right design to the other contracting party. This is because in his model each party can independently and privately learn about the existence of a superior design and must decide whether to reveal its existence to the other party (this theme is further investigated in Tirole, 2015). At least with respect to defective specifications, that of disclosure may be a less vexing issue in light of the “superior knowledge” doctrine. 15

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14 MacLeod and Malcomson (1993) also study how efficient investments can be achieved in the presence of cooperative investments.

15 According to this doctrine, the buyer must disclose special knowledge that is central to the seller’s performance and that the seller cannot be expected to learn from any other source. Failure to meet this requirement implies a violation of contractual obligations. This doctrine arose out of the case Helene Curtis Industries, Inc. v. United States (160 Ct. Cl. 437, 312 F.2nd 774, 1963), in which the Army knew that a costly grinding process was required in order to produce a disinfectant chlorine powder. The Army failed to alert the bidders, although it knew that they were not going to follow an adequate process. The court held that the government had to pay for the extra work to obtain the powder, since it had impliedly warranted that the grinding process was not necessary for performance.
Finally, the paper is closely related to the work by Kvaløy and Olsen (2009), in which there is a positive relationship between how well the contract terms are specified and the probability of verification. Unlike them, I assume that a design failure can always be verified by a court but there is uncertainty as to how the judge will rule. In line with the approach followed by courts, a more specified contract, leaving less discretion to the supplier, increases the likelihood that the buyer will be held liable for design defects. Like Kvaløy and Olsen (2009), I also explore how relational contracting can help achieve the optimal seller’s investment and the efficient level of contract specification (which, in their case is zero, since the only role of specifying contractual terms is to make verification more likely) under different rules which determine damages for contractual breaches.

3 Model

Consider a risk-neutral buyer (she) who wishes to procure a good from a risk-neutral seller (he). There is ex-ante uncertainty as to whether or not the design of the good will fit the buyer’s needs. If the design of the good turns out to be adequate, the buyer receives a benefit valued at $v$, whereas if the design fails, the buyer’s benefit is just $v - h \geq 0$, with $h > 0$. To increase the probability that the design is adequate, denoted $q$, (i) prior to contracting, the buyer can better specify the characteristics of the good she wants to procure, and (ii) during production the seller can invest to improve the quality of the design. The buyer’s specification of the good can also be interpreted as the degree of contract completeness. Therefore, I will say that the contract is more incomplete if fewer resources are expended to specify the characteristics of the good.$^{16}$ As for the seller’s investment, in practice this includes all those activities that can affect the quality of the good, such as paying attention to the job, correcting flaws in the specification furnished by the buyer, directly specifying some portions of the design.

Contract specification and the seller’s investment are denoted by $s$ and $e$, respectively. The probability that the design is correct is $q(s, e) \in [0,1]$. In what follows, I assume that $q(s, e) = \frac{s + e^2}{1 + s + e^2}$. Contract specification costs the buyer $k(s)$ which is a twice continuously differentiable function with $k'(s) > 0$ and $k''(s) > 0$ for all $s \in (0,1)$, with $k(0) = 0$, $k'(0) = 0$, and $k'(1) = +\infty$. The seller’s investment costs $g(e)$, with $g'(e) > 0$ and $g''(e) > 0$, $g'''(e) \geq 0$ for all $e \in (0,1)$, with $g(0) = 0$, $g'(0) = 0$, and $g'(1) = +\infty$.

The buyer’s investment in the specification of the good and the seller’s investment to improve the quality of the design are both assumed to be observable but non-verifiable and relationship-specific. In particular, the resale price of the good if trade between the parties does not take place is zero. In the jargon of Che and Hausch (1999), the buyer’s investment is selfish as it only generates a benefit to herself, whereas the seller’s investment is cooperative as it increases the buyer’s expected value of the good.$^{16}$ This definition of contract incompleteness is close to that introduced by Tirole (2009). One may point out that in my setting only the buyer’s specification contributes to making the contract more complete. However, in Tirole (2009) the seller can incur thinking costs to learn the appropriate design prior to signing the contract, whereas here the seller’s effort to raise the quality of the design is a post-contractual investment.

$^{17}$An examination of the effects of complementarity or substitutability between the buyer’s specification and the seller’s investment is provided in Section 6.
The cost of producing the good is deterministic and is equal to $0 \leq c \leq v - h$. The parties learn whether the design of the good is correct or not at delivery. If a design failure has occurred, the buyer might sue the seller claiming that he is liable for having delivered a defective product.

I carry out the main analysis considering two different scenarios which differ with respect to the information a court can acquire. First, I start with an environment in which the court is unable to assign liability to either party following a design failure and can only compel the buyer to pay the agreed upon price. Second, an environment in which a court is also able to verify whether the specification of the good is defective and assigns liability depending on which contractual party was ultimately responsible for the defects, in line with the approach followed by courts in reality. In this latter scenario, I assume that the ex-ante probability that the buyer is held accountable for a defective good specification, denoted $\phi(s)$, is strictly increasing in $s$ and convex. Implicitly, this means that the buyer is formally delegating responsibility for the design of the good to the seller, who will be held liable unless the court holds that the buyer had real authority over the defective specification.\footnote{This is consistent with existing case-law, which shows that the seller has the burden of proving that the problems stemmed from the defective design specification the buyer had provided. See, for instance, George Sollitt Construction Co. V. U.S, (64 Fed. Cl. 229).}

If the seller is found liable, I assume that the court follows the expectation damages rule, which compensates the buyer for the loss she suffered because of the seller’s negligence. This is the standard rule used to determine damages. An additional reason why I focus on expectation damages is that it is unlikely that the contracting parties can turn to a court to enforce a formal contract which sets payments contingent on whether the specification of the good is correct or not. For instance, in the United States, the Uniform Commercial Code establishes that the parties can liquidate in the contract the damages for breach by either party, but “only at an amount which is reasonable in the light of the anticipated or actual harm caused by the breach”. Moreover “a term fixing unreasonably large liquidated damages is void as a penalty.” (see U.C.C. 2-718). Therefore, the rule to determine damages is ultimately decided by the courts.

In this setting, both the investment and the cost of production have already been borne by the seller when uncertainty resolves and the buyer may sue the seller if the good is defective. Most lawsuits indeed occur once goods are delivered or during production. I assume that an initial contract is necessary to begin production and possible justifications can be a large cost of production and the seller’s having little bargaining power vis-à-vis the buyer or the buyer’s unwillingness to disclose any detail about the characteristics of the good prior to striking a contract with the seller, which includes a confidential agreement, as is typical in many industries, such as defense.\footnote{This stands in contrast to other related papers, like Che and Chung (1999) and Stremitzer (2010), in which uncertainty resolves after the seller’s cooperative investment but before the production cost is borne. These authors also contemplate a scenario in which parties do not avail themselves of a contract and bargain ex-post. This may occur when the seller is asked to develop a prototype and the buyer wants to learn the true benefits before going on with production. Conversely, here the buyer wants a customized good and the parties find out whether the design is defective only when production is complete.} At the contracting stage, the seller receives a share $\alpha \in [0, 1]$ of the expected gains from trade. At delivery, I allow the buyer to offer a price different from the one initially agreed upon with the seller.
The timing of the game is depicted in Figure 1. At the beginning of the game, the buyer chooses the specification $s$ of the design, i.e. the completeness of the contract. Then the contract with the seller for the delivery of the good at price $p$ is signed. The seller invests $e$ to improve the quality of the design and produces the good at a deterministic cost $c$. Between stages 2 and 3, uncertainty resolves and the parties observe whether the design is correct or defective. The good is then delivered and the buyer pays a price $p'$. In the last stage of the game, the parties decide whether to go to court. If at least one party goes to court, the court verifies whether $p' \neq p$ and whether there has been a design failure. In this latter case, the court may assign liability to either party depending on whom had real authority on the design and rules accordingly.

![Figure 1: Timing of the Game](image)

### 3.1 Benchmark

As a benchmark, I first characterize the first-best level of investments $(s^*, e^*)$. Welfare is given by:

$$W(s, e) = v - [1 - q(s, e)]h - k(s) - g(e)$$

Let $e^*$ denote the efficient investment in the quality of the design, given the choice of $s$:

$$e^* = \arg\min_{e \geq 0} \left[1 - s + \frac{e}{2}\right]h + g(e)$$

It follows that:

$$g'(e^*) = \frac{1}{2}h$$

The socially efficient specification of the good is $s^*$:

$$s^* = \arg\min_{s \geq 0} \left[1 - s + \frac{e^*}{2}\right]h + k(s)$$

It follows that:

$$k'(s^*) = \frac{1}{2}h$$

In the next section I carry out the main analysis of the paper. To solve the model, I apply backward induction and I adopt sub-game perfection as equilibrium concept.
4 Court’s Decisions, Under-investment, and Contract Incompleteness

In this section, I focus on the expectation damages rule, which compensates the harmed party for the expected profit she/he would have earned had the contract been performed. I distinguish between two scenarios which entail different verification abilities from the court.

4.1 Non-verifiable Design Failure

First, I study an environment wherein a design failure cannot be verified by a court. In many circumstances, courts are unable to determine whether the good delivered by the seller actually fits the buyer’s requirements and specification or, even if they ascertain a design failure, they do not manage to determine liability (see De Chiara, 2015). Nevertheless, courts are still able to verify whether the price actually paid by the buyer differs from that specified in the formal contract. It must be noted that Kvaløy and Olsen (2009) assume that a court may be able to verify all the contract terms (i.e., both payment and quality) with an endogenous probability which depends on the buyer’s specification of the agreement. In the present setting, the court can always verify whether $p'$ is equal or not to $p$, but may not be able to certify the failure of the design or to assign liability to either party, and this is assumed independent of the degree of contract completeness.

The interpretation of the expectation damages rule that is given here is the following. If the court verifies that $p' \geq p$, that is the buyer has more than fulfilled her contractual obligation, no action is taken. If the court verifies that $p' < p$, it will compel the buyer to comply with the initial contract and pay $p$.

By backward induction, in stage 5 the seller will sue the buyer whenever $p' < p$, since the court will force the seller to abide by the contract and pay $p$. In stage 4, it is without loss of generality to assume that the buyer always offers $p' = p$, irrespective of whether the design is correct or not. To see this, consider that the buyer is always worse off if she pays a price higher than $p$ and never benefits from choosing $p' < p$ since this will spur a lawsuit and the court will enforce the contract. In stage 2, the seller will choose $e$ to maximize his expected payoff:

$$U^N_S(e) = p - c - g(e)$$

(6)

The seller will make no investment, i.e. $e^N = 0$ because his payoff is strictly decreasing in $e$. Intuitively, since the court compels the buyer to abide by the contract but is unable to assign liability for a design failure, the seller has no incentive to invest to improve the quality of the design. The fact that the buyer makes zero cooperative investment is reminiscent of the result of Che and Chung (1999). Below, we will show how this ceases to be the case if the court can assign liability for a defective design.

Anticipating that the seller will not invest, in stage 1 the price satisfies:

$$p^N_S(s) = \alpha[v - c - (1 - \frac{s}{2})h] + c$$

(7)

Namely, the seller is reimbursed of the production cost $c$, and is entitled to a share $\alpha$ of the
gains from trade. Note that the buyer’s investment in the specification of the design is already sunk and, as a result, it does not enter the above expression.

At the beginning of the game, the buyer chooses the specification of the design \( s \) to maximize her expected payoff:

\[
U^N_B(s) = v - p^N(s) - [1 - \frac{s + e^N}{2}]h - k(s)
\]

that is,

\[
U^N_B(s) = (1 - \alpha)[v - c - (1 - \frac{s}{2})h] - k(s) \tag{8}
\]

Maximization yields:

\[
k'(s^N) = (1 - \alpha)\frac{h}{2} \tag{9}
\]

The level of specification chosen by the buyer is decreasing in \( \alpha \). Intuitively the higher the seller’s share of the gains from trade, the lower the buyer’s incentive to write a more complete contract. If the buyer holds all the bargaining power, the level of contract completeness is first best.

**Proposition 1.** Under expectation damages, when the court can only verify transfers, the buyer optimally specifies the good when \( \alpha = 0 \). There is under-specification whenever \( \alpha > 0 \). The seller’s cooperative investment is always zero.

### 4.2 Verifiable Design Failure

Suppose now that the court can also verify whether there has been a design failure and is able to assign liability to either the buyer or the seller. A defective design may represent a breach of contract because the seller, by accepting to provide the good, is responsible for its performance in accordance with the terms of the contract. However, the court will review whether the problems were caused by the seller’s following a defective specification furnished by the buyer. If so, the buyer will be held responsible for the failure, since she had impliedly warranted that if the seller followed her design specification no defect would have arisen.

In what follows, I assume that the parties are not uncertain as to how the court will rule. Namely, if they learn that the design is defective they also learn against whom the court will rule.\(^{20}\) The analysis would not gain much if there were uncertainty as to the court’s decision: What ultimately matters for the seller’s investment and the buyer’s specification are the (i) ex-ante probability of a failure and (ii) the ex-ante probability that the buyer will be held liable for a design which turns out to be defective. These incentives are the same in the two scenarios.

If the seller is held liable for a design failure, he will have to compensate the buyer for the damage that his negligence has caused. Under the expectation damages rule, the seller will have to pay damages equal to the buyer’s lost profit. However, the court may be unable to gauge the entire magnitude of such damages. Especially when the buyer is not the final user of the good but she plans to sell it on the market, there might be a reputation loss as well as other costs that might be incurred, such as penalties for late delivery, which the court may not take into account. Therefore, I assume that the damages awarded by the court are \( \tilde{h} \in (0, h] \).

\(^{20}\) Of course this would imply that the parties can settle outside the courtroom, taking into account what the court’s decision would be. Settling in the shadow of the law does not affect the results of the analysis.
Consider the repercussions of the courts’ approach to determine liability on the contracting parties’ behavior. Akin to the previous subsection, the seller will sue the buyer whenever \( p' < p \). The buyer will sue the seller when there is a design failure and knows that the court will hold the seller accountable. At stage 4, the buyer has no reason to deviate from \( p' = p \).\(^{21}\) In stage 2, the seller chooses how much to invest in the quality of the design:

\[
U_S^E(e, s) = p - c - \left[1 - \frac{s + e}{2}\right][1 - \phi(s)]\tilde{h} - g(e) \tag{10}
\]

The seller’s best response of \( e \) given \( s \) denoted \( e^E(s) \) is:

\[
g'(e^E(s)) = \left[1 - \phi(s)\right]\frac{\tilde{h}}{2} \tag{11}
\]

The seller has an incentive to invest in the quality of the design, i.e., his payoff is no longer strictly decreasing in \( e \). By investing more, the seller can reduce the probability that the design is defective. However, unless \( s = 0 \), the investment will be below the first-best level. More in general, the seller’s investment is more distorted away from efficiency the more complete the contract. Intuitively, a more complete contract increases the probability that the buyer impliedly warrants the soundness of the design, thereby making the seller immune from liability.

In stage 1 the buyer offers:

\[
p^E(s) = \alpha\left[v - c - \left[1 - \frac{s + e^E(s)}{2}\right]h - g(e^E(s))\right] + c + \left[1 - \frac{s + e^E(s)}{2}\right][1 - \phi(s)]\tilde{h} + g(e^E(s)) \tag{12}
\]

and the seller accepts. The price is set in such a way that the seller is entitled to a share \( \alpha \) of the gains from trade and is reimbursed of the production cost \( c \), the investment cost, and the damages that he may be forced to pay if he is held accountable for a design failure.

Prior to contracting, the buyer decides on the specification of the good so as to maximize her utility:

\[
U_B^E(s) = v - p^E(s) - \left[1 - \frac{s + e^E(s)}{2}\right]h - k(s) + \left[1 - \frac{s + e^E(s)}{2}\right][1 - \phi(s)]\tilde{h}
\]

that is,

\[
U_B^E(s) = (1 - \alpha)[v - c - (1 - \frac{s + e^E(s)}{2})h - g(e^E(s))] - k(s) \tag{13}
\]

Note how the probability of winning the lawsuit as well as the amount of damages awarded by the court, \( \tilde{h} \), do not directly affect the buyer’s utility function. They indirectly affect it through their impact on the seller’s investment choice. The optimal specification of the good, denoted \( s^E \), satisfies this equation:

\[
k'(s^E) = (1 - \alpha)\left(\frac{h}{2} + \frac{\tilde{h}}{2} - g'(e^E)\frac{\partial e^E}{\partial s}\right) \tag{14}
\]

\(^{21}\) Alternatively, the buyer after observing a design failure which is ascribable to the seller’s negligence could offer \( p' = p - \tilde{h} \) and no lawsuit would ensue.
Akin to the non-verifiable design failure scenario, the level of specification is decreasing in $\alpha$. If the buyer holds all the bargaining power, the level of contract completeness is no longer first-best, though. This is because the possibility of holding the seller accountable for a design failure motivates the seller to make some cooperative investment. However, the approach followed by courts to determine liability for a defective design prompts the buyer to under-specify the good so as to increase the likelihood that the seller holds real authority over the soundness of the design.

**Proposition 2.** Under expectation damages, when the court can determine liability for a design failure, the buyer always under-specifies the design of the good. Under-specification of the good is magnified compared to the case in which the court only verifies transfers. The seller invests in the quality of the design, but the investment is below first-best.

Therefore, the buyer finds it profitable to strategically under-specify the design of the good, so as to spur the seller’s cooperative investment: A more incomplete contract is indeed associated with a higher equilibrium investment, namely $\frac{\partial e^E(s)}{\partial s} < 0$. Though some investment is spurred, this is suboptimal. To sum up, Proposition 2 implies that $s^E < s^N \leq s^* \text{ and } e^E > e^N$. Therefore, welfare does not unequivocally rise when courts can assign liability for a design failure.

The damages actually awarded by the courts, $\tilde{h}$, affect both the seller’s investment and the buyer’s contract specification. To some extent, the size of $\tilde{h}$ can be related to the courts’ ability to verify damages and determine the true loss suffered by the buyer. Such ability may differ between countries, industries, and may be affected by inherent characteristics of the transaction or the procured good. I now study the effect of an improvement in this verification technology on the equilibrium levels of the seller’s investment and the buyer’s specification. Intuitively, when $\tilde{h}$ increases the seller is more motivated to invest in quality as the court can force him to pay larger damages. The effect in this case is unambiguous. Conversely, the effect of an increase in awarded damages on the buyer’s specification is always positive if $\tilde{h}$ is large enough.

Because of the larger awarded damages, for a given level of contractual specification the seller invests more in the quality of the design. When this effect on the seller’s investment is sizable, the buyer always finds it profitable to increase contractual completeness (i.e. to reduce the distortion from the first-best specification level): Although this negatively affects the seller’s investment, its impact is only of second-order magnitude as compared to that brought about by larger damages. Conversely, when the initial level of $\tilde{h}$ is small enough, the buyer may be better off writing a more incomplete contract in the wake of an increase in $\tilde{h}$ so as to additionally spur the seller’s investment. Note that investment and specification continue to be inefficient even when $\tilde{h} = h$, namely when a court can correctly assess the magnitude of the damages caused by the design failure.

**Remark 1.** When the court awards higher damages, the seller’s investment in the quality of the design unambiguously increases whereas the buyer’s specification of the good increases if $\tilde{h}$ is sufficiently large.
5 Remedies to Inefficiencies

There are some well-known solutions to the under-investment problem, such as vertical integration (Klein et al., 1978 and Williamson, 1979) and the allocation of property rights (Grossman and Hart, 1986). The objective of this section is twofold. First, it attempts to determine whether other possible rules to assign liability for a defective design or to assess damages for breach of contract can help ensure the seller’s optimal investment and the buyer’s optimal contractual specification. I explore two alternatives and I discuss their benefits and limitations. Second, it considers another remedy to the hold-up problem often discussed in the literature, which concerns the possibility of complementing the formal contract with an informal agreement, contingent on information that the parties are able to observe but not to verify in court. In the present setting, the parties could make an informal contract contingent on the investment made by the seller. Since this agreement, known in the literature as relational contract (MacLeod and Malcomson, 1989; Levin, 2003), must be self-enforcing, it can only be sustained if the parties may continue to interact in the future, so that they can informally tie additional business dealings to current performance.

5.1 Expectation Damages and Formal Authority

As a first remedy, I suppose that the court applies the expectation damages rule to determine compensation for breach of contract, but without scrutinizing the specification furnished by the buyer to determine liability. According to this approach, if the buyer contractually places onto the seller the responsibility for the accuracy of the design, the seller will be held accountable for a design failure regardless of whether he followed the buyer’s guidelines and that led to a defect. In other words, formal authority conveys liability for a defective design.

If the seller has been given formal authority over the soundness of the design, in stage 2 he would choose $e$ to maximize the following expected utility:

$$U_F^S(e) = p - c - \left(1 - \frac{s + e}{2}\right)\bar{h} - g(e)$$

The seller’s efficient choice of $e$, denoted $e^F$, is independent of $s$ and solves:

$$g'(e^F) = \frac{\bar{h}}{2}$$

At the contracting stage,

$$p^F(s) = \alpha\left[v - c - \left(1 - \frac{s + e^F}{2}\right)\bar{h} - g(e^F(s))\right] + c + \left(1 - \frac{s + e^F}{2}\right)\bar{h} + g(e^F(s))$$

and the buyer’s expected utility is:

$$U_B^F(s) = (1 - \alpha)\left(v - c - g(e^F(s)) - \left(1 - \frac{s + e^F}{2}\right)\bar{h}\right) - k(s)$$

The buyer’s specification of the good satisfies:

$$k'(s^F) = (1 - \alpha)\frac{\bar{h}}{2}$$
Therefore, the seller’s investment is efficient only if the court awards expectation damages equal to the entire loss of utility borne by the buyer if the design of the good fails. The buyer’s specification of the good is efficient provided that she holds all the bargaining power at the contracting stage.

Whenever \( \tilde{h} > 0 \), the buyer is unambiguously better off contractually placing the authority over the accuracy of the design onto the seller: If she retains formal authority, the seller will not be prompted to invest. In contrast, the buyer’s specification of the good is unaffected by how formal authority is allocated between the parties.

**Proposition 3.** Under expectation damages, if courts determine liability according to whom holds formal authority, the under-investment and under-specification problems are both mitigated and disappear if \( \tilde{h} = h \) and \( \alpha = 0 \), respectively. The seller always holds formal authority.

There are some apparent caveats, though. In particular, it may be impossible or impractical (i.e. entailing an unreasonable and excessive cost) for the seller to deliver the good according to the buyer’s faulty specifications. This is a case which is not contemplated here.

An advantage of adopting this approach would be the reduction of the informational burden for the courts. A court should continue to be able to verify a design failure and estimate the buyer’s loss, but would not have to assess how much latitude the seller had in performing the work.

### 5.2 Liquidated Damages

An alternative way to ensure efficient specification and investment is for the courts to use **liquidated damages**. Under this rule, the court must assign liability for a defective design and, if it holds that the buyer has been harmed, awards the buyer contractually-specified monetary damages. The contract offered by the buyer at stage 2 must be amended: it now consists of a price \( p \) and an amount of money \( D \) the seller commits to pay if the court holds him accountable for a design failure.

In stage 2, the seller chooses \( e \) to maximize:

\[
U^L_S(e, s, D) = p - c - \left[ 1 - \frac{e + s}{2} \right][1 - \phi(s)]D - g(e)
\]  

(19)

the seller’s best response of \( e \) given both \( s \) and \( D \), denoted \( e^L \), is:

\[
g'(e^L(s, D)) = [1 - \phi(s)]\frac{D}{2}
\]  

(20)

The buyer will choose \( s \) and \( D \) to maximize her utility:

\[
U^L_B(s, D) = (1 - \alpha)[v - c - (1 - \frac{s + e^L(s, D)}{2})h - g(e^L(s, D))] - k(s)
\]  

(21)

Maximization yields:

\[
k'(s^L) = (1 - \alpha)\left( \frac{h}{2} + \left( \frac{h}{2} - g'(e^L) \right) \frac{\partial e^L}{\partial s} \right)
\]  

(22)

and

\[
\left( \frac{h}{2} - g'(e^L) \right) \frac{\partial e^L}{\partial D} = 0
\]  

(23)
where from the implicit function theorem:

\[
\frac{\partial e^E(s, D)}{\partial s} = -\frac{\phi'(s) D}{g''(e^E)} < 0
\]

and

\[
\frac{\partial e^E(s, D)}{\partial D} = 1 - \frac{\phi(s)}{2g''(e^E)} > 0
\]

Namely, a more incomplete contract and higher liquidated damages can induce the seller to invest more.

It is easy to see that the buyer induces the seller to make the optimal investment by setting

\[
D_L = \frac{h}{1 - \phi(s)}.
\]

As for the buyer’s specification of the good, this will be first best when she holds all the bargaining power vis-à-vis the seller. In general, the under-specification of the good is the same as when courts are unable to verify a design failure. Put differently, at the equilibrium the buyer does not strategically under-specify the contract to spur the seller’s investment.

**Proposition 4.** Under liquidated damages, the buyer optimally specifies the good when \(\alpha = 0\). There is the same under-specification of the good as when courts do not verify a design failure when \(\alpha > 0\). The seller always makes the optimal cooperative investment.

In terms of welfare, it is possible to conclude that the liquidated damages rule is superior to the expectation damages rule, even when the court only takes into account the formal allocation of authority to determine liability. Both rules require the court to be able to verify that a design failure has occurred and the transfers that the contract specified. However, under the expectation damages rule, the court must also be able to evaluate the true loss of utility suffered by the buyer due to the design failure. If courts are expected to under-estimate damages, i.e. \(\tilde{h} < h\), only liquidated damages can induce the seller to make the optimal investment in the quality of the design.\(^{22}\) Despite its apparent benefits, as argued in Section 3 courts are typically reluctant to enforce such clauses, especially when they set large damages relative to the actual harm caused by the breach, and prefer to award expectation damages.

An analysis of the circumstances under which informal contracting can solve the under-investment and under-specification problems when courts award expectation damages is carried out in the next subsection.

### 5.3 Relational Contracting

Buyers and sellers often interact repeatedly and this may allow them to improve upon the outcome achieved with spot contracts. The aim of this section is to consider what levels of investment and contract completeness can be reached in the presence of repeated interaction. I assume that in every period the buyer wants to procure a different good (e.g. a different building) which requires some investment in its specification and some care in the execution of the work. I assume that both the buyer and the seller discount future payoffs with the same discount factor \(\delta \leq 1\) and I focus on stationary trigger strategies: the parties continue to

\(^{22}\)On the other hand, only under the liquidated damages rule the court scrutinizes the specification provided by the buyer to assign liability.
implement the same per-period actions in every period, unless either of them deviates in which case they revert to the strategies which constitute the subgame-perfect equilibrium of the stage game. The per-period actions that can be implemented clearly depend on both the ability of courts to assign liability for a design failure and the rule followed to award damages. In what follows I determine the conditions under which first-best cooperative investment and contract specification can be achieved.

5.3.1 Non-verifiable Design Failure

When a court can only verify whether the price actually paid by the buyer differs from the one contractually agreed-upon, repeated relationship can be helpful in motivating the seller’s investment with no repercussions on the buyer’s specification of the good.

The per-period set of actions to be played in the subgame perfect equilibrium of the repeated game is a quadruple \((s, p, e, p')\). The trigger strategy for the buyer, denoted \(\sigma_B\), prescribes play in accordance with \((s, p, e, p')\) if there has not been any deviation from \((s, p, e, p')\) in the past (both earlier periods and within the current period), and reversion to the actions which constitute the sub-game perfect equilibrium of the stage game otherwise. Likewise, the trigger strategy for the seller, denoted \(\sigma_S\), prescribes play in accordance with \((s, p, e, p')\) if there has not been any deviation from \((s, p, e, p')\) in the past and reversion to the actions which constitute the sub-game perfect equilibrium of the stage game otherwise.

I now determine what kind of actions relational contracting can sustain, which will be referred to with the superscript \(NR\). First, let \(\beta = p' - p\), namely \(\beta\) is the informal bonus the buyer promises to pay if the seller has chosen the agreed upon investment. As such, \(\beta\) can be a function of the level of investment. Recalling that the buyer will not choose \(p' < p\) in stage 4 because a court would require the seller to receive at least \(p\), consider the buyer’s incentive to pay the promised bonus in stage 4. The buyer is willing to honor her promised payment only if the difference between the expected discounted value of the relational contract and that of reverting to spot contracts is at least as large as the bonus:

\[
U_{NR}^B - U_N^B \geq \frac{1 - \delta}{\delta} \beta_{NR}^{NR} \tag{24}
\]

Consider the seller’s incentive to follow through on his promised investment \(e_{NR}^{NR}\) in stage 2. If he adheres to the relational contract, the seller gets \(U_{NR}^{NR} = p^{NR} + \beta_{NR}^{NR} - c - g(e_{NR}^{NR})\) in every period. For the relational contract to be self-enforcing, it must be that the present value of receiving \(U_{NR}^{NR}\) in every period is at least as large as the payoff the seller obtains in the current period by deviating, denoted \(U_{NR}^{ND}\), and reverting to spot contracts thereafter:

\[
\frac{1}{1 - \delta} U_{NR}^{NR} \geq U_{NR}^{ND} + \frac{\delta}{1 - \delta} U_N^{N}
\]

If the seller reneges, he will not get any bonus from the buyer and the best he can do is to choose \(e_{ND} = 0\) getting \(U_{NR}^{ND} = p^{NR} - c\) in that period. Therefore,

\[
\frac{1}{1 - \delta} (p^{NR} + \beta_{NR}^{NR} - c - g(e_{NR}^{NR})) \geq p^{NR} - c + \frac{\delta}{1 - \delta} U_N^{N}
\]

\[\text{Note that } \beta \text{ need not be a monetary bonus, but can also be the value of additional contracts in other business areas.}\]
which yields
\[ p^{NR} \geq c + U^N + \frac{g(e^{NR}) - \beta^{NR}}{\delta} \] (25)

The buyer chooses \( e^{NR} \) and \( s^{NR} \) to maximize
\[ U^N_B = v - p^{NR} - \beta^{NR} - \left[ 1 - \frac{s^{NR} + e^{NR}}{2} \right] h - k(s^{NR}) \] (26)

The following lemma determines the optimal bonus \( \beta^{NR} \) and the minimum level of the discount factor which ensures that \( e^{NR} = e^* \) and \( s^{NR} = s^* \).

**Lemma 1.** When the court cannot assign liability for a design failure, relational contracting

(i) induces the buyer’s optimal specification of the design and the optimal seller’s cooperative investment by setting:
\[ \beta^{NR} = g(e^{NR}); \] (27)

(ii) and can be sustained if and only if:
\[ \delta \geq \frac{g(e^*)}{h \left( \frac{s^* - s^N}{2} + \frac{e^*}{2} \right) - [k(s^*) - k(s^N)]} \] (28)

To determine the minimum level of \( \delta \) which ensures that optimal specification of the contract and optimal investment in the quality of the design, one considers the minimum \( p^{NR} \) which satisfies (25). However, if (28) holds, relational contracting is surplus-enhancing and there might be a different distribution of its surplus between the contracting parties. Namely, the seller may receive a price higher than \( p^{NR} \), which satisfies with equality his participation constraint.

Furthermore, recall that the smaller \( \alpha \) the larger the surplus associated with formal contracts, because the buyer is more motivated to better specify the characteristics of the good. However, when the relationship is repeated, a lower \( \alpha \) makes it more difficult to sustain a welfare-enhancing relational contract.\(^{24}\)

### 5.3.2 Verifiable Design Failure

When the court assigns liability for a design failure, the per-period set of actions is enriched by the possibility for the buyer to sue or not the seller. As relational contracting concerns the ability of the parties to develop a non-adversarial relationship, it is reasonable to assume that the buyer is not expected to sue the seller after a design failure even when she knows that she will be awarded damages. Interestingly, most of the case-law concerning defective specifications arises from government contracts. One potential explanation is the inability of government officials to use relational incentives: It is typically difficult, if not prohibited, to tie future government contracts to current performance. As a result, resorting to lawsuits is necessary for state or government buyers to provide sellers with incentives to invest in the quality of the design.

I refer to the actions that can be sustained with relational contracting when the court assigns liability for a defective design with the superscript \( ER \). At the time of delivery, it has been

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\(^{24}\)See Baker et al. (1994, 2011) for a more detailed analysis of how imperfect formal contracting can undermine superior relational contracts by increasing the parties’ fall-back position.
assumed that the parties already know whether or not the design is defective. To determine whether optimal relational contracting can be implemented, the maximum temptation to renege must be contemplated (see Levin, 2003; Baker et al., 2002). Therefore, in stage 4, after observing a design failure that the court would ascribe to the seller’s negligence, the buyer is willing to pay the promised bonus \( \beta_{ER} \) and to relinquish to sue the seller only if:

\[
[U_B^{ER} - U_B^{E}] \geq \frac{1 - \delta}{\delta} (\beta_{ER} + \tilde{h})
\]  

(29)

As for the incentives of the seller to make the promised investment in stage 2, it must be that:

\[
\frac{1}{1 - \delta} U_S^{ER} \geq U_S^{ED} + \frac{\delta}{1 - \delta} U_S^{E}
\]

The payoff the seller gets in the current period by deviating is given by:

\[
U_{ED}^S = p_{ER} - c - [1 - \frac{s_{ER} + e_{ED}}{2}][1 - \phi(s_{ER})]\tilde{h} - g(e_{ED})
\]  

(30)

If the seller deviates, the buyer will withhold the promised bonus and sue the seller whenever he can be held liable for the defective design. The level of investment the seller chooses when he deviates satisfies the following equation:

\[
g'(e_{ED}) = \left[1 - \phi(s_{ER})\right] \tilde{h}
\]

Therefore the seller will make good on his promised investment only if:

\[
\frac{1}{1 - \delta} [p_{ER} + \beta_{ER} - c - g(e_{ER})] \geq p_{ER} - c - [1 - \frac{s_{ER} + e_{ED}}{2}][1 - \phi(s_{ER})]\tilde{h} - g(e_{ED}) + \frac{\delta}{1 - \delta} U_S^{E}
\]

which yields:

\[
p_{ER} \geq c + U_S^{E} + \frac{g(e_{ER}) - \beta_{ER}}{\delta} - \frac{1 - \delta}{\delta} \left[1 - \frac{s_{ER} + e_{ED}}{2}\right][1 - \phi(s_{ER})]\tilde{h} + g(e_{ED})
\]  

(31)

In stage 0, the buyer’s utility is given by:

\[
U_B^{ER} = v - p_{ER} - \beta_{ER} - \left(1 - \frac{s_{ER} + e_{ER}}{2}\right) h - k(s_{ER})
\]

The following lemma determines the optimal bonus \( \beta_{ER} \) and under what condition concerning the discount factor, it is possible to attain \( e_{ER} = e^* \) and \( s_{ER} = s^* \).

**Lemma 2.** When the court assigns liability for a design failure, relational contracting

(i) induces the buyer’s optimal specification of the design and the optimal seller’s cooperative investment by setting:

\[
\beta_{ER} = g(e_{ER}) - \left(1 - \frac{s_{ER} + e_{ED}}{2}\right)\tilde{h} + g(e_{ED})
\]  

(32)

(ii) and can be sustained if and only if:

\[
\delta \geq \frac{g(e^*) - g(e_{ED}) + \left(1 - \frac{s^* + e_{ED}}{2}\right)\tilde{h}}{\left(\frac{s^* + e^*}{2} - \frac{s_{ED} + e_{ED}}{2}\right)\tilde{h} - \left[(k(s^*) - k(s_{ED})) + g(e^E) - g(e_{ED}) + \left(1 - \frac{s^* + e_{ED}}{2}\right)\tilde{h}\right]}
\]  

(33)
The bonus that induces optimal cooperative investment is lower than when courts cannot verify a design failure, i.e., $\beta^{ER} < \beta^{NR}$. This is because in the current period the seller’s gain from deviating is less tempting: Since the buyer can threaten to sue the seller if there is a design failure for which he would be held accountable by the court, the seller is induced to invest, albeit sub-optimally, when he reneges on the relational contract. On the other hand, the lure of being awarded the damages $\tilde{h}$ makes it more difficult for the buyer to make good on her promise not to sue the seller.

This subsection has shown how relational contracting can help ensure efficient investment and contract specification provided that the parties are patient enough, i.e. $\delta$ is sufficiently high. An important departure from the existing literature concerns the prediction that contracts will be more complete in the presence of relational contracts. Tirole (2009) finds that contracts will be less complete under relational contracting, because the buyer will continue to devote resources to avert an adjustment cost, but she will be less troubled to forestall renegotiation, i.e. to avoid being held up by the seller.25 In the present setting, when parties can turn to courts for a design failure and only spot contracts are available, I find that the buyer under-specifies the contract to induce the supplier to invest. Under relational contracting, the departures from optimal investment and contract specification can be alleviated and, provided that (33) is satisfied, the efficient outcome is achieved. Therefore, a self-enforcing relational contract may actually lead to a more complete contract and this has implications for empirical work.

6 Complementarity and Substitutability between Investment and Specification

In this section, I relax the assumption that the probability that the design is adequate is independently affected by the buyer’s specification of the good and the seller’s cooperative investment. Arguably, in some occurrences an increase in the buyer’s specification may make the seller’s job of ensuring that the design of the good is flawless harder or easier. For this reason, in what follows I assume that the function $q(s, e)$ is twice continuously differentiable with $q_s > 0$, $q_e > 0$, $q_{ss} \leq 0$, $q_{ee} \leq 0$ and I distinguish between two scenarios. In the first case the investments are substitutes, that is, $q(s, e)$ exhibits decreasing differences in $s$ and $e$: $\frac{\partial^2 q}{\partial s \partial e} = \frac{\partial^2 q}{\partial e \partial s} < 0$ for all $s$ and $e$. In the second case, the investments are complements, that is, $q(s, e)$ exhibits increasing differences in $s$ and $e$: $\frac{\partial^2 q}{\partial s \partial e} = \frac{\partial^2 q}{\partial e \partial s} > 0$ for all $s$ and $e$.26

Denote by $e^*$ and $s^*$ the first-best level of seller’s cooperative investment and buyer’s specification, respectively:27

$$g'(e^*) = q_e(s^*, e^*)h$$

$$k'(s^*) = q_s(s^*, e^*)h$$

Below I focus on the expectation damages rule. When a design failure is unverifiable, the seller is always unwilling to invest, i.e., $e^N = 0$, irrespective of whether there is substitutability or

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25 In a different framework, Kvaløy and Olsen (2009) also find that relational contracting can cause contracts to be more incomplete.

26 The function $q(s, e)$ is submodular in the first case and supermodular in the second case.

27 The first-best investment and specification are derived in the proof of Lemma 3.
complementarity between $e$ and $s$. The buyer’s specification of the contract is then:

$$k'(s^N) = (1 - \alpha)q_s(s^N, 0)h$$  \hfill (34)

Unlike in the case of independence between $e$ and $s$, the seller’s zero investment when the design failure is non-verifiable now impacts on the buyer’s choice of the degree of contractual incompleteness. Suppose first that specification and investment are substitutes so that the incremental gain to choosing a higher contractual specification is larger when $e = e^N = 0$ then when $e = e^* > 0$. If $\alpha = 0$ the buyer over-specifies the contract with respect to first-best. In contrast, if specification and investment are complements, the incremental gain to choosing a higher contractual specification is larger when $e = e^* > 0$ then when $e = e^N = 0$. Therefore, when there is complementarity, even for $\alpha = 0$ it holds that $s^N < s^*$. 

**Lemma 3.** When the court can only verify transfers,

(i) the seller’s cooperative investment is always zero;

(ii) if specification and investment are substitutes, there exists $\hat{\alpha} \in (0, 1)$ such that if $\alpha < \hat{\alpha}$ the buyer over-specifies the contract relative to first-best and if $\alpha > \hat{\alpha}$ the buyer under-specifies the contract relative to first-best. If $\alpha = \hat{\alpha}$, contractual specification coincides with the first-best level;

(iii) if specification and investment are complements, the buyer always under-specifies the contract as compared to first-best.

Suppose now that a design failure is verifiable. The first-order conditions which determine the seller’s choice of the cooperative investment and the buyer’s choice of the contractual specification mirror those displayed in Section 4 and are reported below:

$$g'(e^E) = q_e(s^E, e^E)[1 - \phi(s^E)]h$$  \hfill (35)

$$k'(s^E) = (1 - \alpha)\left(q_s(s^E, e^E)h + [q_e(s^E, e^E)h - g'(e^E)]\frac{\partial e^E(s)}{\partial s}\right)$$  \hfill (36)

The seller is induced to make some investment in the quality of the design so as to reduce the probability that a failure will occur and he will be held liable by a court. However, the level of the investment will generally not be optimal. When investment and specification are substitutes, the buyer writes a more incomplete contract when a court can assign responsibility for a design failure than when it cannot, i.e. $s^E < s^N$. The reason is twofold: First, as the seller is making some positive investment the gain the buyer attains by choosing a higher $s$ is reduced, namely, $q_s(s, e) < q_s(s, 0)$ for all $e > 0$; second, as usual the buyer finds it profitable to strategically reduce specification so as to encourage the seller’s investment, i.e. $\frac{q_e(s^E)}{\partial s} < 0$. When investment and specification are complements, contract completeness can actually increase as compared to when courts do not assign liability for a design failure. This is because the seller’s investment increases the gain the buyer obtains when she better specifies the good, i.e. $q_s(s, e) > q_s(s, 0)$ for all $e > 0$. This can be offset by the buyer’s willingness to spur the seller’s cooperative investment by reducing specification. However, it must be noted that when the investments are
complements, the buyer might better encourage the seller’s investment by increasing instead of reducing specification. This occurs because the seller’s return to the cooperative investment is higher when the contract is more complete (complementarity effect). Put differently, when investment and specification are complements, it may be the case that $\frac{\partial e(s)}{\partial s} > 0$.

**Lemma 4.** When the court can assign liability for a design failure,

(i) the seller’s cooperative investment is positive but generally non optimal;

(ii) If specification and investment are substitutes, the contract is more incomplete when the court can assign liability for a design failure than when it cannot, i.e. $s^E < s^N$;

(iii) If specification and investment are complements, the contract is more incomplete when the court can assign liability for a design failure than when it cannot only if:

$$\frac{q_{eE}(s^E, e^E)}{q_e(s^E, e^E)} < \frac{\phi'(s^E)}{1 - \phi(s^E)}.$$ (37)

The lemma characterizes a necessary condition for the contract to be more incomplete when the design failure can be verified. If inequality (37) holds, a marginal increase in $s$ has a stronger impact on the hazard rate of the probability that the buyer will be held accountable for the design failure than on the marginal probability that a failure will occur. Intuitively, when this condition is verified, a more complete contract discourages the seller to invest because the effect on the probability that the buyer will be held accountable for a design failure dominates the complementarity effect.

The following proposition summarizes the main results of this section.

**Proposition 5.** Irrespective of whether specification and investment are substitutes or complements, the seller is motivated to invest, albeit non-optimally, only if the court assigns liability for a design failure. If specification and investment are substitutes, contract completeness is lower when a court can assign liability for a design failure than when it cannot. If specification and investment are complements, contract completeness may be higher or lower when a court can assign liability for a design failure than when it cannot.

The proposition highlights the robustness of our main results: The approach followed by courts to assign liability for a design failure motivates the seller to make some investment, which will be different from first-best though, and distorts the buyer’s specification of the contract. In particular, unless the complementarity effect is too strong, contracts will be more incomplete when courts can hold either party accountable for defects in the design.\(^\text{28}\)

\(^\text{28}\)Results similar to those shown in this section can be derived when pursuing an alternative modeling approach wherein only the seller’s investment reduces the probability of failure whereas the buyer’s specification raises the value of the good, that is, $v(\cdot)$ is an increasing function of $s$, and affects the seller’s investment cost, that is $g(e, s)$ exhibits increasing or decreasing differences in $e$ and $s$.\(^\text{29}\)
7 Conclusions

This paper has shown how the approach followed by courts to assign liability for a defective design may motivate the seller to make a cooperative specific investment but, at the same time, may induce the buyer to under-specify the characteristics of the good. The seller is willing to invest to avoid being obliged by a court to pay the damages due to a defective design. The buyer refrains from optimally specifying the good to reduce the likelihood that she will be held accountable for a design failure. The implications may even be more far-reaching as this approach may stifle innovation. To illustrate this point, consider a buyer who needs to procure a good and must decide whether to adopt a standard design or a more customized option, which might be superior but entails more uncertainty and would require more investment. The buyer might decide to use the standard design anticipating that what she could achieve by choosing the customized design would be unsatisfactory. Indeed, the buyer would need to under-specify the customized design so as to spur the seller’s investment, which would nonetheless be less than efficient.

The paper has also highlighted some possible remedies to the under-investment and under-specification problems in so providing some important policy guidance to courts. For instance, courts can improve welfare by awarding damages depending on how the formal authority over the design was allocated between the contracting parties. However, in a repeated setting this may decrease the surplus that can be achieved through relational contracts, making it more unlikely for the parties to sustain an informal agreement that achieves first-best. In fact, this may provide a rationale for the current approach followed by courts.

The results of the paper are all the more relevant given the increasing reliance in the Design-Build project delivery system, which is often perceived also as a way to shift design risk from the owner to the contractor.29 In fact, since the courts review the owner’s specification to assign liability for a design failure, the risk can be shifted only by delegating real and not merely formal authority.

There are a number of additional aspects which may enrich the present analysis and that I leave for future research. First, I have so far abstracted from legal enforcement costs. In reality these costs exist and may be substantial thereby discouraging the party presumably harmed by the breach of contract to go to trial and, in turn, stifling compliance by the other party who anticipates that his opportunistic behavior will go unpunished.30 Second, often times the seller’s investment is unobservable to the buyer and it would be interesting to study the repercussion of non-observability on parties’ behavior and economic outcomes.

Furthermore, the approach followed by courts may also impact on the trade decision. To analyze this issue, I must consider a setting in which the seller has not yet incurred the production cost once uncertainty over the soundness of the design resolves and, depending on the damages caused by a design failure, it may not be profitable to go forward with production. This setting

29 According to a study conducted by RSMeans Analytics, the market share for Design-Build was 38 percent for non-residential buildings in the U.S. in 2014 (see "Design-Build Project Delivery Market Share and Market Size Report").

30 Coviello et al. (2014) theoretically put forward and empirically bear out a positive relationship between contract enforcement costs and opportunistic behavior.
would be closer to that of Che and Chung (1999).
Appendix

Proof of Proposition 2

To see that the buyer under-invests in the specification of the good, consider that it is possible to obtain \( \frac{\partial e^E(s)}{\partial s} \) from the Implicit Function Theorem, since the second order derivative of the seller’s utility with respect to \( e \) is different from zero, and it yields:

\[
\frac{\partial e^E(s)}{\partial s} = -\frac{\phi'(s)\frac{h}{2}}{g''(e^E(s))}
\]

Note that both the numerator and the denominator are positive, since \( \phi(\cdot) \) is an increasing function and \( g(\cdot) \) is a convex function. Therefore, the sign of \( \frac{\partial e^E(s)}{\partial s} \) is negative.

Moreover,

\[
\frac{h}{2} - g'(e^E) > 0
\]

since

\[
g'(e^E) = [1 - \phi(s^E)]\frac{h}{2}
\]

and, as a result,

\[
\frac{h}{2} - g'(e^E) = \frac{h}{2} - [1 - \phi(s^E)]\frac{h}{2}
\]

which can be rewritten as

\[
\frac{1}{2}(h - [1 - \phi(s^E)]\tilde{h})
\]

which is positive for all \( \tilde{h} \leq h \) and \( \phi(s) \leq 1 \) with at least one strict inequality. Therefore,

\[
k'(s^E) = (1 - \alpha) \left( \frac{h}{2} + \frac{h}{2} - g'(e^E) \frac{\partial e^E}{\partial s} \right) < k'(s^N)
\]

As for sufficiency, consider the second-order condition of the buyer’s problem:

\[
(1 - \alpha) \left( \frac{\phi'(s^E)\tilde{h}}{2} \frac{\partial e^E}{\partial s} + \frac{1}{2}(h - [1 - \phi(s^E)]\tilde{h}) \frac{\partial^2 e^E}{\partial s^2} \right) - k''(s^E) < 0
\]

where

\[
\frac{\partial^2 e^E}{\partial s^2} = -\frac{\phi''(s^E)\tilde{h}g''(e^E(s)) - \phi'(s^E)\frac{h}{2}g''(e^E(s))\frac{\partial e^E}{\partial s}}{(-g''(e^E(s)))^2}
\]

is non-positive. To see this, note that the denominator is positive and, as a result, the sign of \( \frac{\partial^2 e^E}{\partial s^2} \) is the opposite of the sign of the numerator. The numerator is non-negative since it is the difference between a non-negative term (recall that \( \phi''(s) \) is non-negative) and a term which is non-positive. □
Proof of Remark 1

Consider the system of two equations in three parameters in a neighborhood of \((e^E, s^E)\):

\[
F_1(e, s, \tilde{h}) = 0 \Leftrightarrow (1 - \phi(s)) \frac{\tilde{h}}{2} - g'(e) = 0
\]

\[
F_2(e, s, \tilde{h}) = 0 \Leftrightarrow (1 - \alpha) \left( \frac{\tilde{h}}{2} - \left( \frac{h}{2} - g'(e) \right) \frac{\phi'(s) \tilde{h}}{2g''(e)} \right) - k'(s) = 0
\]

Consider the Jacobian matrix of this system with respect to \((e, s)\):

\[
J_F(e, s) = \begin{pmatrix}
(1 - \alpha) \left( \frac{\phi'(s) h}{2} + \left( \frac{h}{2} - g'(e) \right) \frac{\phi'(s) h g''(e)}{2g''(e)^2} \right) & -\phi'(s) \frac{h}{2} \\
-\phi''(s) \frac{h}{2} & -(1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi''(s) h g''(e)}{2g''(e)^2} - k''(s)
\end{pmatrix}
\]

Recall that to apply the Implicit Function Theorem the determinant of the Jacobian matrix must be different from zero. This is given by:

\[
(1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi''(s) \tilde{h}}{2} + g''(e) k''(s)
\]

\[
+(1 - \alpha) \left( 1 + \left( \frac{h}{2} - g'(e) \right) \frac{g''(e)}{g''(e)^2} \right) \left( \phi'(s) \frac{\tilde{h}}{2} \right)^2
\]

which is always strictly positive. Indeed, the buyer’s utility function \(U^E_{u}\) is strictly concave.

We can thus use the Cramer’s rule to determine the effect of an increase in \(\tilde{h}\) on the seller’s investment and the buyer’s specification. Specifically, for the effect of an increase in \(\tilde{h}\) on the equilibrium cooperative investment:

\[
\frac{\partial e^E}{\partial h} = \left| \begin{array}{cc}
\frac{1 - \phi(s)}{2} & -\phi'(s) \frac{h}{2} \\
(1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi'(s) h}{2g''(e)} & -(1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi''(s) h g''(e)}{2g''(e)^2} - k''(s)
\end{array} \right|
\]

Since the denominator is positive, the marginal effect of an increase in \(\tilde{h}\) on \(e^E\) is positive if and only if the numerator is positive:

\[
\frac{1 - \phi(s)}{2} (1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi''(s) \tilde{h}}{2g''(e)} + \frac{1 - \phi(s)}{2} k''(s)
\]

\[
+ \phi'(s) \frac{\tilde{h}}{2} (1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi'(s)}{2g''(e)}
\]

which is always the case. Therefore, a marginal increase in \(\tilde{h}\) unambiguously increases \(e^E\).

For the effect of an increase in \(\tilde{h}\) on the equilibrium contractual specification:

\[
\frac{\partial s^E}{\partial h} = \left| \begin{array}{cc}
\frac{-g''(e)}{2} & -\phi''(s) \frac{h}{2} \\
(1 - \alpha) \left( \frac{\phi'(s) h}{2} + \left( \frac{h}{2} - g'(e) \right) \frac{\phi'(s) h g''(e)}{2g''(e)^2} \right) & (1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi''(s) h g''(e)}{2g''(e)^2}
\end{array} \right|
\]

\[
+ \phi'(s) \frac{\tilde{h}}{2} (1 - \alpha) \left( \frac{h}{2} - g'(e) \right) \frac{\phi'(s)}{2g''(e)}
\]

which is always the case. Therefore, a marginal increase in \(\tilde{h}\) unambiguously increases \(e^E\).
Again, since the denominator is positive, the effect is positive if and only if the numerator is positive:

\[-(1 - \alpha)(\frac{h}{2} - g'(e)) \frac{\phi'(s)}{2}\]

\[+ (1 - \alpha) \frac{1 - \phi(s) \phi'(s) \tilde{h}}{2} \left(1 + \frac{h}{2} - g'(e) \frac{g'''(e)}{(g''(e))^2}\right)\]

This is positive only if:

\[\frac{1 - \phi(s)}{2} \tilde{h} \left(1 + \frac{h}{2} - g'(e) \frac{g'''(e)}{(g''(e))^2}\right) > \left(\frac{h}{2} - g'(e)\right)\]

Therefore, a sufficient condition for the effect of an increase in \(\tilde{h}\) on \(s^E\) to be positive is that:

\[\frac{1 - \phi(s)}{2} \tilde{h} > \left(\frac{h}{2} - g'(e)\right)\]

and replacing \(g'(e)\) with \(\frac{1 - \phi(s)}{2} \tilde{h}\), the condition can be restated as

\[\tilde{h} > \frac{h}{2(1 - \phi(s))}\]

Hence, it is possible to conclude that a marginal increase in \(\tilde{h}\) unambiguously increases \(s^E\) if \(\tilde{h}\) is large enough.

\[\square\]

**Proof of Proposition 4**

Recall that

\[g'(e^L) = [1 - \phi(s^L)] \frac{D^L}{2}\]

To satisfy (23), buyer must set:

\[D^L = \frac{h}{1 - \phi(s^L)}\]

By doing so, (22) becomes:

\[k'(s^L) = (1 - \alpha) \frac{h}{2}\]

For the second-order sufficient conditions, consider the Hessian matrix of the buyer's objective function at \((s^L, D^L)\):

\[H = (1 - \alpha) \begin{pmatrix} -g''(e) \left(\frac{\partial e}{\partial s}\right)^2 & -g''(e) \frac{\partial e}{\partial s} \frac{\partial e}{\partial D} & -g''(e) \left(\frac{\partial e}{\partial D}\right)^2 \\ -g''(e) \frac{\partial e}{\partial s} \frac{\partial e}{\partial D} & -g''(e) & -g''(e) \left(\frac{\partial e}{\partial D}\right)^2 \end{pmatrix}\]

Note that this is negative definite, since (i) the leading principal minors of order 1 have negative sign, i.e.:  

\[-g''(e) \left(\frac{\partial e}{\partial s}\right)^2 > 0\]

\[-g''(e) \frac{\partial e}{\partial s} \frac{\partial e}{\partial D} > 0\]

\[-g''(e) \left(\frac{\partial e}{\partial D}\right)^2 > 0\]
(ii) the determinant of the Hessian matrix is positive:

\[
\frac{k''(s)}{1 - \alpha g''(e)} \left( \frac{\partial e}{\partial D} \right)^2 > 0
\]

\[\Box\]

**Proof of Lemma 1**

Consider the buyer’s utility function (26) and express \(\beta^{NR}\) as a function of the investment the seller is expected to make.

\[
U^{NR}_B = v - p^{NR} - \beta^{NR}(e^{NR}) - [1 - \frac{s^{NR} + e^{NR}}{2}]h - k(s^{NR})
\]

I want to determine which level of \(\delta\) allows the parties to maximize total surplus. For this reason, consider the minimum \(p^{NR}\) which satisfies (25):

\[
U^{NR}_B = v - c - \frac{g(e^{NR}) - \beta^{NR}(e^{NR})}{\delta} - \beta^{NR}(e^{NR}) - U^N_S - [1 - \frac{s^{NR} + e^{NR}}{2}]h - k(s^{NR}) \quad (A1)
\]

Maximization with respect to \(s^{NR}\) yields:

\[
k'(s^{NR}) = \frac{h}{2} \quad (A2)
\]

that is, the buyer optimally specifies the design of the good. Maximization with respect to \(e^{NR}\) yields:

\[
\frac{\partial \beta^{NR}(e^{NR})}{\partial e^{NR}} + \frac{g'(e^{NR}) - \frac{\partial \beta^{NR}(e^{NR})}{\partial e^{NR}}}{\delta} = \frac{h}{2} \quad (A3)
\]

By setting, \(\beta^{NR}(e^{NR}) = g(e^{NR})\), the buyer can induce the seller to optimally invest in the quality of the design.

For the buyer to find it profitable to implement the relational contract it must be that (24) is satisfied. Consider

\[
U^{NR}_B = v - c - g(e^{NR}) - \alpha [v - c - (1 - \frac{s^{N} + e^{N}}{2})h] - [1 - \frac{s^{NR} + e^{NR}}{2}]h - k(s^{NR})
\]

and

\[
U^N_B = (1 - \alpha)[v - c - (1 - \frac{s^{N} + e^{N}}{2})h] - k(s^{N}).
\]

Therefore, (24) holds if and only if:

\[
U^{NR}_B - U^N_B = \left( \frac{s^{NR} + e^{NR}}{2} - \frac{s^{N} + e^{N}}{2} \right)h - [k(s^{NR}) - k(s^{N})] - g(e^{NR}) \geq \frac{1 - \delta}{\delta} g(e^{NR})
\]

which yields

\[
\delta \geq \frac{g(e^{NR})}{h \left( \frac{s^{NR} + e^{NR}}{2} - \frac{s^{N} + e^{N}}{2} \right) - [k(s^{NR}) - k(s^{N})]}
\]

and substituting \(e^*\) to \(e^{NR}\) and \(s^*\) to \(s^{NR}\) gives (28).
Finally, to see that $p^{NR}$ satisfies the seller’s participation constraint, consider that the seller is willing to accept to complement the formal contract with the informal one if:

$$U^{NR}_S \geq U^N_S$$

and

$$U^{NR}_S = p^{NR} + \beta^{NR} - c - g(e^{NR}) = U^N_S.$$

**Proof of Lemma 2**

To determine when the parties can maximize total surplus, set the minimum price which satisfies (31) and replace it in the buyer’s utility function:

$$U^{ER}_B = v - \beta^{ER} - \left(1 - \frac{s^{ER} + e^{ER}}{2}\right) h - k(s^{ER})$$

$$- c - U^E_S - \frac{g(e^{ER}) - \beta^{ER}}{\delta} + \frac{1 - \delta}{\delta} \left(1 - \frac{s^{ER} + e^{ED}}{2}\right)[1 - \phi(s^{ER})] \tilde{h} + g(e^{ED})$$

Set:

$$\beta^{ER} = g(e^{ER}) - \left(1 - \frac{s^{ER} + e^{ED}}{2}\right)[1 - \phi(s^{ER})] \tilde{h} + g(e^{ED})$$

and note that this bonus induces the seller to make the optimal investment and the buyer to optimally specify the design of the good, i.e. $e^{ER} = e^*$ and $s^{ER} = s^*$.

For the buyer to find it profitable to implement the relational contract it must be that (29) is satisfied. Consider

$$U^{ER}_B = v - c - \alpha[v - c - (1 - \frac{s^{ER} + e^{ER}}{2}) h - g(e^{ER})] - \left(1 - \frac{s^{ER} + e^{ER}}{2}\right) h - k(s^{ER}) - g(e^{ER})$$

and

$$U^E_B = (1 - \alpha) \left(v - c - (1 - \frac{s^{ER} + e^{ER}}{2}) h - g(e^{ER})\right) - k(s^{ER}).$$

Therefore, (29) holds if and only if:

$$U^{ER}_B - U^E_B = \left(\frac{s^{ER} + e^{ER}}{2} - \frac{s^E + e^E}{2}\right) h - [k(s^{ER}) - k(s^E)] - [g(e^{ER}) - g(e^E)]$$

$$\geq \frac{1 - \delta}{\delta} \left(\frac{g(e^{ER}) - [1 - \frac{s^{ER} + e^{ED}}{2}][1 - \phi(s^{ER})] \tilde{h} + g(e^{ED}) + \tilde{h}}{1 - \frac{s^{ER} + e^{ED}}{2}}\right)$$

This can be rewritten as

$$\left(\frac{s^{ER} + e^{ER}}{2} - \frac{s^E + e^E}{2}\right) h \geq \frac{1}{\delta} [g(e^{ER}) - (1 - \delta)(e^{ED}) - \delta g(e^E)] + [(k(s^{ER}) - k(s^E))]$$

$$+ \frac{1 - \delta}{\delta} \left(1 - [1 - \frac{s^{ER} + e^{ED}}{2}][1 - \phi(s^{ER})]\right) \tilde{h}.$$
This can be rearranged as:

\[
\delta \left( \frac{s_{ER} + e_{ER}}{2} - \frac{s + e}{2} \right) h - \delta \left( k(s_{ER}) - k(s) \right) \\
\geq g(e_{ER}) - (1 - \delta) g(e_{ED}) - \delta g(e) + (1 - \delta) \left( 1 - \frac{s_{ER} + e_{ED}}{2} \right) [1 - \phi(s_{ER})] \tilde{h}
\]

or:

\[
\delta \left( \frac{s_{ER} + e_{ER}}{2} - \frac{s + e}{2} \right) h - \left( k(s_{ER}) - k(s) \right) + g(e) - g(e_{ED}) \\
+ \delta \left( 1 - \frac{s_{ER} + e_{ED}}{2} \right) [1 - \phi(s_{ER})] \tilde{h} \\
\geq g(e_{ER}) - g(e_{ED}) + \left( 1 - \frac{s_{ER} + e_{ED}}{2} \right) [1 - \phi(s_{ER})] \tilde{h}
\]

and substituting \( e^* \) to \( e_{ER} \) and \( s^* \) to \( s_{ER} \) it is possible to attain (33).

\[ \square \]

**Proof of Lemma 3**

First we illustrate the first-best investment and specification levels.

Welfare is given by:

\[
W(s, e) = v - [1 - q(s, e)] h - k(s) - g(e)
\]  (A4)

Let \( e^*(s) \) denote the efficient investment in the quality of the design, given the choice of \( s \):

\[
e^*(s) \equiv \arg \min_{e \geq 0} [1 - q(s, e)] h + g(e)
\]  (A5)

It follows that:

\[
g'(e^*(s)) = q_e(s, e^*(s)) h
\]

The socially efficient specification of the good is \( s^* \):

\[
s^* \equiv \arg \min_{s \geq 0} [1 - q(s, e^*(s))] h + k(s) + g(e^*(s))
\]  (A6)

It follows that:

\[
k'(s^*) = q_e(s^*, e^*) h
\]

The first-best level of investment in the quality of the design satisfies: \( e^* = e^*(s^*) \).

When the court is unable to assign liability for a design failure, \( U_N^S = p - c - g(e) \)

As a result, \( e_N = 0 \) irrespective of whether investment and specification are substitutes or complements. Buyer’s chosen contractual specification satisfies:

\[
k'(s_N) = (1 - \alpha) q_e(s_N, 0) h
\]

\[ \text{Note that the derivative of (A6) with respect to } s \text{ yields:}
\]

\[
-q_e(s, e^*(s)) h + k'(s) + \left[ g'(e^*(s)) - q_e(s, e^*(s)) \right] \frac{\partial e^*(s)}{\partial s}
\]

the terms \( g'(e^*(s)) \) and \( q_e(s, e^*(s)) \) cancel each other out. It is a simple application of the Envelope Theorem.
As a result, when there is complementarity, as compared to first best the buyer always writes a more incomplete contract. When there is substitutability, the contract can be more or less complete than in the first best, depending on the value of $\alpha$. Let:

$$G^N(\alpha) = (1 - \alpha)q_s(s^N, e^N)h$$

$G^N$ is continuous in $\alpha$ and its domain is $[0, 1]$. When $\alpha = 1$:

$$G^N(1) = k'(0) = 0$$

and when $\alpha = 0$:

$$G^N(0) = M > k'(s^*) = q_s(s^*, e^*)$$

because $q_{se} < 0$ and $e^* > 0 = e^N$. Therefore, for the Intermediate Value Theorem, there exists $\hat{\alpha} \in (0, 1)$ such that

$$G^N(\hat{\alpha}) = (1 - \hat{\alpha})q_s(s^N, e^N)h = k'(s^*)$$

namely, $s^N = s^*$. Then for $\alpha \in (\hat{\alpha}, 1]$ the buyer under-specifies the contract relative to first best and for $\alpha \in [0, \hat{\alpha})$ the buyer over-specifies the contract relative to first best.

\[\square\]

**Proof of Lemma 4**

In stage 2, the seller faces this problem:

$$\max_{e \geq 0} p - c - [1 - q(s, e)][1 - \phi(s)]h - g(e)$$

The seller’s best response of $e$ given $s$ yields:

$$g'(e^E(s)) = q_e(s, e^E)[1 - \phi(s)]h$$

The price satisfies the following:

$$p^E = c + g(e^E(s)) + [1 - q(s, e^E(s))][1 - \phi(s)]h$$

$$+ \alpha(v - [1 - q(s, e^E(s))]h - c - g(e^E(s)))$$

In stage 0, the buyer chooses how much to invest in contract completeness:

$$U^E_B = (1 - \alpha)(v - c - g(e^E(s)) - [1 - q(s, e^E(s))]h) - k(s)$$

which I assume to be strictly concave in $s$ to guarantee a unique equilibrium specification level.\(^{32}\) Maximization yields:

$$k'(s^E) = (1 - \alpha) \left( q_e(s^E, e^E)h + [q_e(s^E, e^E)h - g'(e^E)} \frac{\partial e^E(s)}{\partial s} \right)$$

Irrespective of whether the investments are complements or substitutes

$$q_e(s^E, e^E)h - g'(e^E) > 0$$

\(^{32}\) Admittedly this can be very demanding when $q(s, e)$ is submodular and requires that $k(s)$ be sufficiently strictly convex.
To see this, consider that \( g'(e^E) = q_e(s^E, e^E)[1 - \phi(s^E)]h \) and, as a result,

\[
q_e(s^E, e^E)h - g'(e^E) = q_e(s^E, e^E)h - q_e(s^E, e^E)[1 - \phi(s^E)]\tilde{h} = q_e(s^E, e^E)(h - [1 - \phi(s^E)]\tilde{h}) > 0
\]

The sign of \( \frac{\partial E(s)}{\partial s} \) may be affected by the complementarity or substitutability between investments:

\[
\frac{\partial E(s)}{\partial s} = -\frac{(q_e(s, e^E)[1 - \phi(s)] - q_e(s, e^E)\phi'(s))\tilde{h}}{q_e(s, e^E)[1 - \phi(s)]h - g''(e^E(s))}
\]

The denominator is always negative since it is the difference between a first term which is non-positive and a second term which is positive. Therefore, the sign of \( \frac{\partial E(s)}{\partial s} \) coincides with that of the numerator.

If investments are substitutes, \( q_{es} < 0 \) and because \( q_e(s, e^E)\phi'(s) > 0 \) the numerator is negative. As a result, \( k'(s^E) < (1 - \alpha)q_e(s^E, e^E)h \). In addition, since the seller makes a positive investment and the incremental gain to choosing a higher \( s \) is smaller when \( e \) is larger, i.e. \( q_s(s, e^E) < q_s(s, e^N) \) for all finite \( s \), it is possible to conclude that \( s^E < s^N \).

If investments are complements, \( q_{es} > 0 \) and then the marginal effect of \( s \) on \( e^E \) is negative if and only if:

\[
\frac{q_{es}(s^E, e^E)}{q_e(s^E, e^E)} < \frac{\phi'(s^E)}{1 - \phi(s^E)}
\]

However, this is just a necessary condition for the contract to be more incomplete when the court can assign liability for a design failure than when it cannot. This is because the seller makes a positive investment and the incremental gain to choosing a higher \( s \) is higher when \( e \) is larger, i.e. \( q_e(s, e^E) > q_e(s, e^N) \) for all finite \( s \). \( \square \)
References


