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Courts' Decisions, Cooperative Investments, and Incomplete Contracts

by

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Abstract

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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 before and 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). Since the investment is *cooperative*, in that it generates a direct benefit to the trading party, the under-investment problem is especially severe, as shown by 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 relationship-specific investment, a court may be able to verify a design failure. However, even if the seller is contractually responsible for the accuracy of the design, the buyer may not be wholly immune from liability. Quite surprisingly, in the U.S. the 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 was 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] In contrast, in countries like Canada and the U.K. courts assign liability depending on how design authority was contractually allocated between the parties.

The objective of this paper is to study how different approaches followed by courts in the presence of a defective design affect sellers' cooperative investment and buyers' specification of the good. To the best of my knowledge, this is the first article which analyzes this topic in the economics literature. In the model, prior to contracting with a

[1] Examples of the dire consequences of poorly planned projects abound. One notable case is that of the Big Dig in Boston, a troubled megaproject whose development was plagued by design flaws, in addition to delays and cost overruns (see "10 years later, did the Big Dig deliver?" on Boston Globe, December 29, 2015). Other examples are the Constitution Bridge in Venice, which initially lacked a wheelchair access (see "Lawsuit gives rise to new bridge of sighs in Venice" on The Independent, January 12, 2014), and the alleged design failure of the Millennium Tower, a residential high-rise in San Francisco which has sunk 16 inches and tilted 2 inches since it opened in 2008 (see "SF's landmark tower for rich and famous is sinking and tilting" on the San Francisco Chronicle, August 1, 2016).

[2] This courts' approach to assign liability is extensively described in Section 2.1.

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 buyer spends more resources to specify the good. 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. The seller's cooperative investment is 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.

I compare two alternative approaches to assign liability for a defective design. First, I analyze a more standard legal setting where the seller is always held liable for defects, whenever he has formal authority over the accuracy of the design (*formal-authority regime*). Second, I study a legal setting where the court will ascertain whether the buyer provided a defective specification, in which case she will be held liable even if she had formally delegated design authority to the seller (*real-authority regime*). In both regimes, I assume that courts follow the *expectation damages* rule to assess damages for a design failure. The expectation damages rule is the standard rule to determine damages and its intent is to put the harmed party in the same position he or she would have been had the contract been performed.

The court's ability to assign liability for a design failure can prompt the seller to make some investment so as to avoid being compelled by a court to pay damages to the buyer. However, consistently with the approach adopted by courts in the real-authority regime, the ex-ante 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 characteristics of the good that she initially specified. The paper sheds light on the strategic under-specification of the good induced by the real-authority regime: The buyer finds it profitable to write a more incomplete contract to delegate more real authority over the soundness of the design to the seller, thereby prompting him to invest more. In contrast, in a formal-authority regime such strategic effect is absent and both the buyer's specification of the good and the seller's investment are closer to first-best.

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. Furthermore, I show that an economic justification for the real-authority regime cannot be provided by its role in facilitating the use of superior relational contracting. While this regime is associated with larger benefits from using relational contracts than the formal-authority regime (because welfare under spot transactions is lower), it also entails a greater spot gain from reneging on the informal agreement. This is because the spot punishment ensuing a seller's deviation by under-investing is milder when the courts assign liability to the party who held real authority. Intuitively, the buyer will be willing to bring a lawsuit if there is a design failure, since the relational agreement has been breached. The seller will always have to pay damages in the formal-authority regime, whereas he may not be held liable in the real-authority regime. As a result, optimal relational contracting may be more easily sustained if courts only take into account the allocation of formal authority to assign liability for defects. Hence, it is very difficult to justify the real-authority regime on efficiency grounds.

The remainder of 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 characterizes two benchmarks. Section 4 presents the main analysis and Section 5 explores relational contracting. Section 6 discusses several extensions and 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 I subsequently 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]

[3] An interesting and extensive analysis of these legal cases is provided by Loulakis (2013).

One of the most important construction law cases in the United States is *United States v. Spearin*[4] 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]

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 design 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

[4]248 U.S. 132, 39 S. Ct. 59, 63 L. Ed. 166 (1918).

[5]Although I 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.

[6]This 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 specifications" create an obligation for the supplier. *PCL Construction Services, Inc. v. United States* - 47 Fed. Cl. 745 (2000) states:

> *The warranty applies only to "design specifications" because only by utilizing specifications in that category does the government deny the contractor's discretion and require that work be done in a certain way.*

[7]8 Cl. Ct. 42 (1985).

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 wherein, as opposed to Design-Bid-Build, the builder (i.e. the seller) also provides the design of the project. Although Design-Build is often regarded 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 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 pertains to 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

[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 BCA 31,306.) the seller had to develop shop drawings but wanted to be compensated for some extra-work. The Board of Contract Appeals agreed, since the contract documents and specifications provided by the buyer took the discretion away from the seller in those areas which caused the additional work.

[11] 987 F.2d 743, United States Court of Appeals, Federal Circuit 1993.

of the project, the buyer and the seller share responsibility towards third parties.[12]

In contrast, in other countries the approach followed by courts enables the buyers to more easily shift design risk to the sellers. In the UK, the buyer does not generally impliedly warrant the feasibility of the design specification that she provides, as can be seen from *Thorn v London Corporation*[13] and *Tharsis Sulphur & Copper Co v McElroy & Sons*.[14] Furthermore, in a design and build contract, specifying the intended use of the good implicitly imposes an obligation onto the seller to ensure that the finished work will be fit for that purpose.[15] Similarly, in Canada, warranties of fitness for purpose may render the seller liable for defects in the design, even if their work comply with the buyer's specification.[16]

2.2 Related Literature

The paper is closely linked to the literature on endogenous contract incompleteness. I borrow from Bajari and Tadelis (2001) the idea that the buyer can costly specify the characteristics of the good so as to reduce the likelihood of an ex-post design failure. In Bajari and Tadelis (2001) 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 advantageous when the procured good is complex in that there is a high likelihood of renegotiating the initial agreement. My research question is novel as I focus on how different approaches followed by courts to assign liability for a defective design affect the seller's investment choice and the buyer's incentive to specify the good. Following Bajari and Tadelis (2001), other authors, such as Ganuza (2007), Chakravarty and MacLeod (2009), and Tirole (2009), have developed models wherein the buyer makes an investment into planning.[17] 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

[12]See Corte di Cassazione Civile no. 2977, 20/3/98 and no. 467, 13/01/2014.

[13]1 App Cas 120 (1876).

[14]3 App Cas 1040 (1878).

[15]See *Greaves & Co. v Baynham Meikle & Partners*, 1 WLR 1095 (1975).

[16]See *Greater Vancouver Water District v. North American Pipe & Steel Ltd.* BCCA 337 (2012).

[17]A different approach which similarly leads to contract incompleteness is put forward by Bolton and Faure-Grimaud (2009, 2010) who study agents who face time costs and may optimally refrain from acquiring full information about the payoffs of certain actions.

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 a defective design, that of disclosure may be a less vexing issue in light of the "superior knowledge" doctrine.[18]

The paper is also 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 increases the likelihood that the buyer will be held liable for design defects because it leaves less discretion to the seller. 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. The efficient level of contract completeness is zero in their model, since the only role of specifying contractual terms is to make verification more likely. In contrast, a certain degree of contract completeness is socially beneficial in my paper because it decreases the probability of a design failure.

By studying how different legal regimes affect investment incentives, the paper also shares some important features with the literature on the effects of different breach remedies on trade and investment decisions, which was pioneered 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 own 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). The present model is closer to the strand of this literature which focuses on a *cooperative* investment, i.e., an investment that 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

[18] 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.

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 (2012) 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. Ganglmair (2017) characterizes the optimal quality threshold below which the buyer can rightfully reject delivery to induce optimal cooperative investment when contract enforcement is imperfect. When the contract can specify investment, Schweizer (2006) establishes that bilateral expectation damages, according to which damages can be claimed if either 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. 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 delivered good turns out to be defective. Moreover, the main aim of this literature is to determine which rule for assessing damages for a breach of contract is the most efficient, whereas 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.[19]

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 be adequate. If the design of the good turns out to be correct, 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)

[19]Another literature to which this paper is linked focuses on efficient contracting to overcome the hold-up problem highlighted by Hart and Moore (1988) when investments are observable but not verifiable. Efficient selfish investment can be achieved (i) by adequately specifying the default option if courts enforce specific performance as shown by Chung (1991) and Aghion et al. (1994), or (ii) by writing simple option contracts as shown by Nöldeke and Schmidt (1995). For studies concerning efficient cooperative investments, see MacLeod and Malcomson (1993), Che and Hausch (1999), and Edlin and Hermalin (2000). In particular, Che and Hausch (1999) show that efficiency cannot be achieved when the parties cannot commit not to renegotiate the contractual terms. For related experimental evidence, see Hoppe and Schmitz (2011).

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.[20] 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 working out 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 $q(s, e) = \frac{s+e}{2}$, since this simple formulation is very useful to build intuition: It will be shown that the approach followed by courts to assign liability for a defective design may make the parties' best responses interdependent, despite $q(s, e)$ being additive separable in s and e.[21] 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 $k(0) = k'(0) = 0$. 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 $g(0) = g'(0) = 0$. Moreover, $k'(1) > \frac{h}{2}$ and $g'(1) > \frac{h}{2}$ so that it is not optimal to guarantee that the design is correct with probability 1.

The buyer's investment in the specification of the good and the seller's investment to improve the quality of the design are observable but non-verifiable. Both investments are relationship-specific in that 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.

The timing of the game is depicted in Figure 1. At the beginning of the game, the buyer chooses the specification $s \in [0, 1]$ 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 $e \in [0, 1]$ to improve the quality of the design and produces the good at a deterministic cost which is normalized to zero for simplicity. Between stages 2 and 3, uncertainty resolves and the parties observe whether the design is correct or defective. In

[20]This definition of contract incompleteness is close to that introduced by Tirole (2009). However, in my setting only the buyer's specification contributes to making the contract more complete, whereas in Tirole's also the seller's investment does. This difference owes to the different timing of the investment: The seller can incur thinking costs to learn the appropriate design *prior to* signing the contract in Tirole (2009), whereas the seller's effort to raise the quality of the design is a post-contractual investment in the present paper.

[21]An examination of the effects of complementarity or substitutability between the buyer's specification and the seller's investment is provided in Section 6.2.

the last stage of the game, if there has been a design failure, the buyer decides whether or not to sue the seller for having delivered a defective good. If there is a lawsuit, the court may assign liability to either party and rule accordingly.

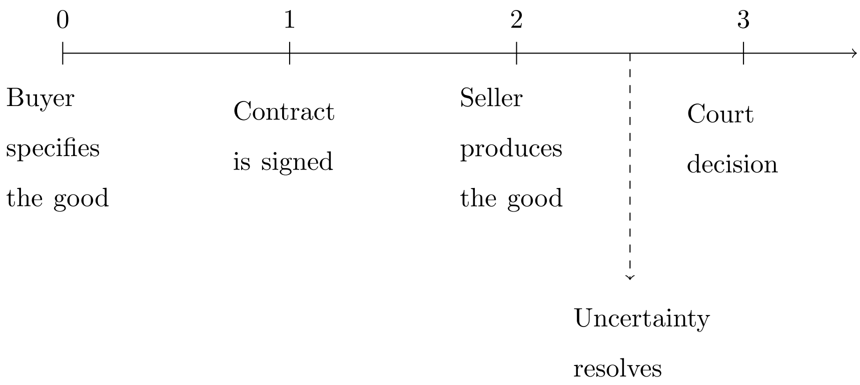


Figure 1: Timing of the Game

I carry out the main analysis considering two different regimes concerning the approach followed by courts to assign liability for a defective design. In both cases, if there is a lawsuit and 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 breach of contract. The reason for the focus on the expectation damages rule is twofold. First, this rule is the default remedy followed by courts to determine damages. Second, it is unlikely that the contracting parties can turn to a court to enforce a formal contract setting very large payments contingent on whether the design 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, courts effectively limit the maximum payments the parties can recover in the wake of a contract breach.[22]

I assume that an initial contract is necessary to begin production and possible justifications can be the seller's little bargaining power, or the buyer's unwillingness to disclose any sensitive detail about the characteristics of the good prior to striking a contract with the seller, which may include a confidential agreement, as is typical in many industries, such as defense. Moreover, while in the model the cost of production is normalized to zero, in reality this may be so large that a liquidity-constrained seller could not advance

[22]In Section 6.1, it is shown that, with the liquidated damages rule, the parties will be able to implement the first-best cooperative investment if payments are unbounded.

it. Parties contract cooperatively according to the generalized Nash bargaining solution in which the buyer receives a share $\alpha \in [0, 1]$ of the expected gains from trade.

To evaluate the effects of different courts' approaches, it is useful to compare them against two benchmarks: (i) the first-best outcome where design specification and cooperative investment are chosen to maximize social welfare; and (ii) an environment in which courts cannot verify whether the design of the good is defective or not.

3.1 Benchmark: First-best

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

$$W(s, e) = v - [1 - q(s, e)]h - k(s) - g(e). \tag{1}$$

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

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

It follows that the optimal investment is characterized by the following first-order condition:

$$g'(e^*) = \frac{1}{2}h. \tag{3}$$

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

$$s^* \equiv \arg\min_{s \geq 0} \left[1 - \frac{s + e^*}{2}\right] h + k(s). \tag{4}$$

It follows that:

$$k'(s^*) = \frac{1}{2}h. \tag{5}$$

Because $q(s, e)$ is additive separable in its arguments, the first-best investment and specification choices are independent of one another.

3.2 Benchmark: Non-verifiable Design Failure

Now, I study an environment wherein a design failure cannot be verified by a court. In many instances, courts are unable to determine whether the good delivered by the seller actually fits the buyer's requirements and specification or, even if a design failure is ascertained, they do not manage to determine liability (see De Chiara, 2018). Nevertheless, courts are still able to verify whether the good specified in the formal contract has been delivered. The interpretation of the expectation damages rule that is given here is the following. If the court verifies that the good has been delivered, no action is taken. If the court verifies that delivery has not occurred, it will compel the seller to pay the buyer's lost profit, which equals v.[23]

The model, in all its variants, is solved by backward induction and sub-game perfection is adopted as equilibrium concept. It is without loss of generality to assume that the seller always produces the good, since she would be forced to pay damages for non-delivery.[24] Therefore, in stage 2, the seller will choose e to maximize his expected payoff:

$$U_S^N(e) = -g(e). \tag{6}$$

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

$$p^N(s) \in \arg\max_{p\in\mathbb{R}} \quad p^{1-\alpha} \times \left(v - p - \left[1 - \frac{s}{2}\right] h\right)^{\alpha},$$

which yields:

$$p^N(s) = (1-\alpha)\left(v - \left[1 - \frac{s}{2}\right] h\right). \tag{7}$$

Namely, the seller captures a share $1-\alpha$ 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 affect the negotiated price.

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

$$U_B^N(s) = \alpha\left(v - \left[1 - \frac{s}{2}\right] h\right) - k(s). \tag{8}$$

Maximization yields:

$$k'(s^N) = \alpha\frac{h}{2}. \tag{9}$$

The level of contract completeness chosen by the buyer equalizes the marginal cost of specification and its private marginal benefit, which coincides with the share of the social

[23]In a different setting, 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 contrast, I posit that the court can always verify whether delivery has occurred (price is paid when the contract is signed), but may not be able to certify the failure of the design of the delivered good or to assign liability to either party, and this is assumed independent of the degree of contract completeness.

[24]Even if the court were not be able to entirely assess the buyer's valuation of the good, a seller who fails to deliver the good would likely be compelled to pay damages which are at least as high as the price initially received from the buyer. As it will be shown below, $p \geq 0$, which implies that the seller does not have any incentive not to produce the good.

marginal benefits accruing to the buyer. As a consequence, the level of specification chosen by the buyer is increasing in α. 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. *If courts can only verify transfers, the buyer optimally specifies the good only when* $\alpha = 1$. *There is under-specification whenever* $\alpha < 1$. *The seller's cooperative investment is always zero.*

4 Verifiable Design Failure

In this section I analyze a setting in which courts are able to verify whether the design fails to meet the buyer's requirements and I distinguish between two different approaches to assign liability for defects. Note that 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. This does not necessarily imply that the seller will have to pay damages: As extensively discussed in Section 2.1, in some countries courts will ascertain whether the problems stemmed from a defective specification furnished by the buyer and that the seller simply followed. 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.

4.1 Expectation Damages and Formal Authority

In some countries, such as Canada and the UK, if the buyer contractually places on 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 and the courts do not scrutinize the specification furnished by the buyer to determine liability. Consistently, in what follows I will refer to this legal setting as the *formal-authority regime* and I will denote the parties' equilibrium choices with the superscript F.

If a court verifies that a design failure has occurred and the seller holds formal authority over the accuracy of the design, he will have to compensate the buyer for the harm that she has suffered. Under the expectation damages rule, damages should equal the buyer's lost profit. However, the court may be unable to gauge the entire magnitude of the buyer's harm. There are a number of possible reasons for under-compensation which are widely discussed in the law and economics literature and include, but are not limited to, the buyer's inability to prove her losses with reasonable certainty (Eisenberg, 2005 and Ganglmair, 2017) or the courts' reluctance to award "speculative" lost profits ascribable to the breach (see Schwartz, 1979, Part II, and references therein). 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 a court may not take into account. Therefore, because contract enforcement may be imperfect, I assume that the damages awarded by the courts are $\tilde{h} \in [0, h]$.

Consider now the repercussions of this legal regime on parties' equilibrium behavior. Notice that the seller is always willing to produce the good in stage 2 and, if he has been given formal authority over the soundness of the design he will choose e to maximize the following expected utility:

$$U_S^F(e) = -\left[1 - \frac{s+e}{2}\right]\tilde{h} - g(e). \tag{10}$$

The seller has an incentive to invest in the quality of the design because his payoff is no longer strictly decreasing in e. By investing more, the seller can reduce the probability that the design is defective and, as a result, decrease the probability that he will pay damages. The seller's efficient choice of e, denoted e^F, is independent of s, and solves:

$$g'(e^F) = \frac{\tilde{h}}{2}. \tag{11}$$

The marginal cost of the cooperative investment equals the seller's marginal benefit of avoiding to pay damages $\tilde{h}$ to the buyer. At the contracting stage, the parties agree to trade at the following price:[25]

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

As a result, the buyer's expected utility is:

$$U_B^F(s) = \alpha\left(v - g(e^F(s)) - \left[1 - \frac{s+e^F}{2}\right]h\right) - k(s). \tag{13}$$

The buyer chooses s to maximize the above expression. The equilibrium specification of the good satisfies:

$$k'(s^F) = \alpha\frac{h}{2}. \tag{14}$$

[25] To see why, note that:

$$p^F(s) \in \arg\max_{p\in\mathbb{R}} \left(p - \left[1 - \frac{s+e^F}{2}\right]\tilde{h} - g(e^F)\right)^{1-\alpha} \times \left(v - p - \left[1 - \frac{s+e^F}{2}\right](h - \tilde{h})\right)^{\alpha}.$$

Therefore, the seller's investment is first-best only if the court awards 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 and is zero if $\alpha = 0$. Whenever $\tilde{h} > 0$, the buyer is unambiguously better off contractually placing the authority over the accuracy of the design on 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.

The following proposition summarizes these results and compares cooperative investment and good specification attainable under a regime of formal authority with those attainable if courts can only verify transfers.

Proposition 2. *In a formal-authority regime, the under-investment problem that arises when a design failure is non-verifiable is mitigated and disappear if $\tilde{h} = h$. The under-specification problem continues to arise whenever $\alpha < 1$ and is of the same magnitude. The buyer always finds it profitable to delegate formal authority to the seller.*

Under the formal-authority regime, welfare is strictly increasing in both the buyer's bargaining power and the courts' ability to correctly assess the buyer's harm. The former mitigates the design under-specification problem, because the buyer can appropriate a higher fraction of the gains from a more complete contract. The latter alleviates the under-investment problem, because the seller is willing to expend more resources to avoid paying higher damages.

4.2 Expectation Damages and Real Authority

Now, I analyze a legal environment in which a court assigns liability depending on which contractual party was ultimately responsible for the defects, in line with the approach followed by courts in countries such as the United States.

Henceforth, I assume that if the design fails the parties are not uncertain as to how the court will assign liability. Namely, if they learn that the design is defective they also learn against whom the court will rule.[26] 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 failure and (ii) the ex-ante probability that the buyer will be held liable for a design which turns out to be defective, that I will define momentarily. These incentives are the same in the two scenarios.

[26] Of course this implies 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.

Suppose that the buyer formally delegates responsibility for the accuracy of the design of the good to the seller. Let $\phi(s) \in [0,1]$ be the ex-ante probability that the buyer is held accountable for a defective good specification. I assume that $\phi(\cdot)$ is strictly increasing in s and is (weakly) convex, with $\phi(0) = 0$. This means that the seller has "residual responsibility" over the accuracy of the design and that the buyer will be paid damages unless the court holds that she had real authority over the portion of the design which caused the failure.[27] Accordingly, in what follows I will refer to this legal setting as the *real-authority regime* and I will denote the parties' equilibrium choices and utility functions with the superscript R. In this regime, the seller will have to pay damages if he has been formally delegated authority and the court holds that it was his negligence which caused the design failure.

It is important to provide some motivation for the assumption that the ex-ante probability that the buyer is held accountable for a defective design specification is increasing in s. Intuitively, a higher s means that the buyer has taken care of a greater number of aspects of the design of the good, thereby reducing the probability of failure. On the other hand, a higher s also increases the likelihood that the buyer has overlooked some critical details on the portions of the design she herself has specified, and those oversights ultimately lead to a failure. Existing case-law shows that a buyer can wholly transfer design risk to the seller by refraining from specifying the good. As soon as she specifies some aspects of the design or of the performance, the buyer runs the risk of making some mistakes which will lead to a failure for which she will be held accountable, despite having formally delegated design authority to the seller. The risk that a flaw could be attributed to the buyer's design specification is higher when such specification is more detailed. For instance, in *J.E. Dunn Construction Co. v. General Services Administration*,[28] the buyer's drawings concerning a complex curtain wall of a new federal courthouse in Kansas City specified the design, shapes and profiles of the aluminium members. When problems stemming from their design arose, the Board of Contract Appeals held that the government had to bear the additional costs to overcome those defects because it had provided a very detailed specification: Such rich specification both left little discretion to the seller and implied that it could be relied upon to perform the work.

Consider the repercussions of this courts' approach to determine liability on the contracting parties' behavior. In stage 3, the buyer will sue the seller when there is a design failure and she knows that the court will hold the seller liable. In stage 2, the seller is

[27]This is consistent with the 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).

[28]GSBCA No. 14477,00-1 BCA 30,806.

always willing to produce the good and chooses how much to invest in the quality of the design to maximize his expected utility:

$$U_S^R(e) = -\left[1 - \frac{s+e}{2}\right][1-\phi(s)]\tilde{h} - g(e). \tag{15}$$

The seller expects to pay damages $\tilde{h}$ to the buyer if the design turns out to be defective and the court holds him liable. Despite $q(s,e)$ being additive separable in s and e, the seller's best response of e is a function of s, and is denoted $e^R(s)$:

$$g'(e^R(s)) = [1-\phi(s)]\frac{\tilde{h}}{2}. \tag{16}$$

The seller has an incentive to invest in the quality of the design: By investing more, the seller can reduce the probability that the design is defective and, as a consequence, that he will have to pay damages. However, unless $s = 0$, the investment will always be below the first-best level, even if the awarded damages could make the buyer whole. 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 parties agree to trade at the following price:[29]

$$\begin{aligned} p^R(s) = (1-\alpha)&\left(v - \left[1 - \frac{s+e^R(s)}{2}\right]h - g(e^R(s))\right) \\ &+ \left[1 - \frac{s+e^R(s)}{2}][1-\phi(s)\right]\tilde{h} + g(e^R(s)). \end{aligned} \tag{17}$$

The price is set in such a way that the seller captures a share $1-\alpha$ of the gains from trade and is reimbursed of both 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:

$$U_B^R(s) = \alpha\left(v - \left[1 - \frac{s+e^R(s)}{2}\right]h - g(e^R(s))\right) - k(s). \tag{18}$$

[29]To see why, note that:

$$\begin{aligned} p^R(s) \in \arg\max_{p\in\mathbb{R}} &\left(p - \left[1 - \frac{s+e^R(s)}{2}\right][1-\phi(s)]\tilde{h} - g(e^R(s))\right)^{1-\alpha} \\ &\times\left(v - p - \left[1 - \frac{s+e^R(s)}{2}\right]h + \left[1 - \frac{s+e^R(s)}{2}\right][1-\phi(s)]\tilde{h}\right)^{\alpha}. \end{aligned}$$

Neither the probability of winning the lawsuit nor the amount of damages awarded by the court, $\tilde{h}$, directly affect the buyer's utility function. They indirectly affect it through their impact on the seller's investment choice, though. The equilibrium specification of the good, denoted s^R, satisfies this equation:

$$k'(s^R) = \max\left\{0, \alpha\left(\frac{h}{2} + \left[\frac{h}{2} - g'(e^R)\right]\frac{\partial e^R}{\partial s}\right)\right\}. \tag{19}$$

At the equilibrium, the marginal cost of specifying the design equates the fraction of the marginal benefit that the buyer appropriates, which is the term in the round brackets, provided that it is non-negative. This term is composed of $h/2$, which is the social benefit, and $[\frac{h}{2} - g'(e^R)]\frac{\partial e^R}{\partial s}$, which corresponds to the marginal effect of higher specification on the equilibrium cooperative investment.

Akin to both the non-verifiable design failure scenario and the formal authority regime, the level of specification is weakly increasing in α. If the buyer holds all the bargaining power, the level of contract completeness is no longer first-best, though. The approach followed by courts to determine liability for a defective design induces 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, thereby prompting a higher cooperative investment. The following proposition summarizes these results and compares cooperative investment and good specification attainable under a regime of real authority with those attainable if courts can only verify transfers.

Proposition 3. *In a real-authority regime, 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.*

The proposition highlights how, under the real-authority regime, the buyer finds it profitable to strategically under-specify the design of the good so as to spur the seller's cooperative investment. With a more incomplete contract, the seller is more likely to hold real authority over the soundness of the design: For this reason, a higher level of cooperative investment is associated with a decrease in contract specification, namely $\frac{\partial e^R}{\partial s} < 0$. Although some investment is spurred, this is always suboptimal, unless the buyer entirely refrains from specifying the good and damages are wholly compensatory.

Comparing equilibrium investment and specification in the regimes of real and formal authority, it is possible to see how the former regime leads to lower welfare. In the real-authority regime, the seller's incentives to invest are dampened because he anticipates that the buyer may be held liable for a design failure. Therefore, $e^R \leq e^F \leq e^*$, and the first inequality holds strictly whenever $s^R > 0$. The buyer strategically under-specifies the design to induce the seller to invest more. As a result, the equilibrium specification level is always higher under the formal-authority regime: $s^R < s^F \leq s^*$. The proposition compares welfare between the two regimes.

Corollary 1. *If $\alpha > 0$, social welfare is always strictly higher when the courts assign liability according to formal authority than real authority. If $\alpha = 0$, the two approaches have identical welfare effects.*

It is also worth pointing out that the real-authority regime cannot be justified on the grounds of a reduced informational burden for the courts. To the contrary, under the formal-authority regime, a court must just be able to verify the occurrence of a design failure and estimate the buyer's loss, but does not have to ascertain whether the defects stemmed from a defective specification furnished by the buyer.

The model offers some testable implications. All else being equal, when the sellers are contractually responsible for the soundness of the design, we should observe that buyers pay higher prices in a regime of formal authority. This is because the design risk is effectively shifted onto the sellers. In addition, design failures should occur less often, since both contracting parties will find it profitable to devote more resources to improve the design of the good. Furthermore, as the gains from trade the parties can share are larger, we can expect sellers to be more profitable in a regime of formal authority. However, as the lure of larger profits can attract more firms to enter the market, sellers may not end up being better off in this regime.

In the remainder of this section, I analyze in turn the effects of changes in α and $\tilde{h}$ on cooperative investment and specification level in the real-authority regime, and then I comment on one of the chief modeling assumptions. When courts only consider formal authority, it is immediate to see that higher damages awarded by the courts increase cooperative investment in equilibrium with no effect on contract specification. Conversely, the distribution of the gains from trade between the parties affects s^F but not e^F. In a regime of real authority, investment and specification are interdependent and comparative statics results are more interesting.

Bargaining power distribution. The higher the buyer's bargaining power α, the greater the benefits of a more comprehensive design that accrue to the buyer. Hence, she has stronger incentives to expend resources on specifying the contract. As seen, the same effect arises under different regimes too. However, in a real-authority regime, when the design is more specified the seller is prompted to invest less because the likelihood that he will hold accountability for defects falls. Since the effect on e^R is mediated through that on s^R, the relationship between α and overall welfare in this regime is always positive.[30]

Awarded damages. 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 of the procured good. An improvement in this verification technology may have opposing effects 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 to improve the quality of the design as the court can force him to pay larger damages. The sign of this effect is unambiguous. Conversely, the effect of an increase in the awarded damages on the buyer's specification is always positive if $\tilde{h}$ is large enough. For a given level of contractual specification, the seller invests more in the quality of the design because of the larger awarded damages. When this positive effect on the seller's investment is sizable, the buyer always finds it profitable to increase contractual completeness, thereby reducing the distortion from the first-best specification level: Despite its negative effect on the seller's investment, its impact is only of second-order magnitude as compared to that brought about by larger damages. In contrast, when the initial level of $\tilde{h}$ is small enough and, as a result, the seller's cooperative investment is low, the buyer may be better off writing a more incomplete contract in the wake of an increase in $\tilde{h}$: A reduction in s^R engendered by an increase in the awarded damages additionally spurs the seller's investment and the trade-off between specification and cooperative investment is positive because of the convexity of the cost functions. Figure 2 illustrates the relationship existing between $\tilde{h}$ and the equilibrium choices of investment and specification. Specifically, Panel (b) shows how e^R is positively affected by an increase in $\tilde{h}$, whereas Panel (a) graphically represents the non-monotonic relationship existing between contract specification and awarded damages.[31] To summarize:

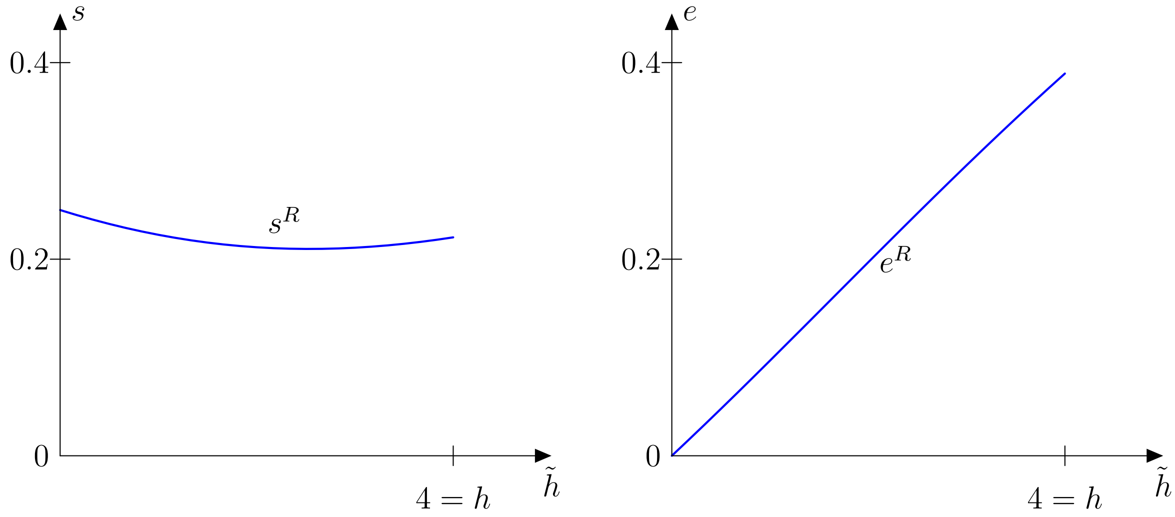
Remark 1. *When the court awards higher damages, the seller's investment in the quality of the design unambiguously increases whereas the buyer's specification of the good increases if $\tilde{h}$ is sufficiently large.*

Even though an increase in $\tilde{h}$ may have opposite effects on investment and contract specification, the latter is of second-order magnitude so that it is possible to conclude that welfare usually increases if courts are better able to assess damages. Finally, note that

[30] A formal proof is available upon request.

[31] The following values were taken to draw Figure 2: $\alpha = 0.5$, $h = 4$, $g(e) = 2e^2$, $k(s) = 2s^2$, $\phi(s) = s$.

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.



(a) s^R as a function of $\tilde{h}$ (b) e^R as a function of $\tilde{h}$

Figure 2: Awarded damages, cooperative investment, and contract specification.

Design Specification and Liability. The model deliberately pursues a reduced-form approach to study the effects of a legal regime wherein courts inspect the specification provided by the buyer to assign liability for a design failure. The conclusion that the real-authority regime will prompt the buyer to strategically under-specify the design would not be substantially altered by developing a more sophisticated model, though. One possibility could be the following. Suppose that one of $N \geq 2$ non contractible and equally likely states of the world will occur after stage 2. A state of the world is a combination of actual project characteristics that enables the buyer to derive full value v from the good. Each state of the world can be ex-ante specified by either the buyer or the seller through a detailed description of the project features (e.g., the material to be used, the type of foundations). If the state of the world which realizes has not been ex-ante specified, the design fails with probability 1, whereas it fails with a fixed probability $\rho \in (0, 1)$ otherwise. Players bear a positive cost to specify the states of the world which increases in the number of specified states at a more than proportional rate. Suppose that it is efficient that both the buyer and the seller devote some resources to state specification. Following a design failure, a court is able to observe which state of the world has occurred and whether and by whom it has been specified. In a regime of formal authority, the court will assign liability for a design failure to the party who holds formal authority, irrespective of which state realized and who specified it, if any. In a regime of real authority, the court will assign liability for a design failure to the party who specified the realized state, if any, and to whom holds formal authority otherwise. Namely, the court places responsibility on the party who was in charge of the specification of the realized state of the world.

Also under these assumptions, a regime of real authority shields the buyer from responsibility if she delegates design authority to the seller and fully refrains from specification. By specifying a state of the world the buyer increases the probability that the design is adequate, but at the same time she increases the likelihood that she will be held accountable for a design failure (i.e. if that state realizes but a failure occurs). Since specifying more states reduces the seller's expected accountability, it dampens his incentives to invest in state specification. Therefore, this court's approach prompts the buyer to under-specify states in order to provide the seller with stronger incentives to invest.

5 Relational Contracting

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). Another remedy to the hold-up problem often discussed in the literature 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.

In the real world, this solution may be viable because buyers and sellers often interact repeatedly and, as a result, they may be able to improve upon the outcome achieved with spot contracts. One result which is well established in the literature on relational contracting is that worse spot transactions can more easily sustain superior relational agreements: Contracting parties are less tempted to breach the informal agreement if spot transactions are more inefficient, so that the surplus that relational contracting can generate is larger.[32] Thus, the real-authority regime, which is associated with a lower level

[32]Seminal studies on the relationship between formal and informal contracts are those by Baker et al. (1994) and Schmidt and Schnitzer (1995). Recently, Itoh and Morita (2015) have shown that formal contracts can help alleviate the hold-up problem in a repeated setting when the relation-specific investment

of welfare when only spot contracts are used, may facilitate superior relational contracting and could consequently find a justification on efficiency grounds. However, I will show that this may not be the case in this setting because the real-authority regime also entails a larger spot gain from breaching the informal agreement than the formal-authority regime. This may actually render first-best investment and specification more difficult to sustain.

More specifically, in this section I assume that in every period the buyer wants to procure a new good (e.g. a different building) which requires some investment in its specification and some care in the planning and 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 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.[33] The per-period actions that can be implemented clearly depend on both the ability of courts to verify a design failure and the approach followed to assign liability.

As a modeling shortcut, I assume that the buyer promises to pay the seller an informal bonus β if he has chosen the agreed-upon investment. Two remarks are in order. First, β need not be a direct monetary transfer, but can also be the monetary value of additional contemporaneous contracts awarded to the seller in the same or in a different business area. Second, similar conclusions could be drawn from the analysis if discretionary monetary transfers were not available, which is arguably the case if the buyer is a public agency. If so, the buyer can still resort to other measures to ensure the seller's cooperation when interaction is repeated over time. These tools include debarment and suspension actions (respectively, permanent and temporary exclusions from participating in competitive tendering procedures) or handicaps and ratings on past performance, which often carry a large weight in the selection of contract awardees.[34] An analysis of how the main results of this section carry through when these alternative tools are used can be provided upon request. In what follows I determine the conditions under which first-best cooperative

is cooperative and reduces the surplus under no trade (i.e., it has a threat-point effect).

[33]This restriction to stationary strategies is without loss of generality, given my information assumptions (see Levin, 2003).

[34]The 2011 report by the U.S. Government Accountability Office GAO-12-102R highlights the importance of non-price factors such as ratings on past performance and prior experience in the award of most procurement contracts. See Albano et al. (2017) for a discussion of how discriminatory evaluation criteria are used in public procurement in the U.S. and in Europe. These authors show that handicaps can be effective in sustaining cooperative outcomes where sellers provide observable but non-verifiable quality. In a different setting, Ganuza et al. (2016) show that a firm can take costly actions to reduce the probability of an accident motivated by the need to maintain its market reputation (i.e., the consumers stop purchasing the good if it turns out to be defective).

investment and contract specification can be achieved.[35]

5.1 Non-verifiable Design Failure

When courts 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 without negative 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, β). The trigger strategy for the buyer, denoted σ_B, prescribes play in accordance with (s, p, e, β) if there has not been any deviation from (s, p, e, β) 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 σ_S, prescribes play in accordance with (s, p, e, β) if there has not been any deviation from (s, p, e, β) 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. Consider the buyer's incentive to pay the promised bonus in stage 3, namely the *buyer's dynamic-enforcement constraint* (BDE). 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 promised bonus:

$$\frac{\delta}{1-\delta}(U_B^{NR} - U_B^{N}) \geq \beta^{NR}, \tag{BDE^{NR}}$$

where

$$U_B^{NR} = v - p^{NR} - \beta^{NR} - \left[1 - \frac{s^{NR} + e^{NR}}{2}\right] h - k(s^{NR}).$$

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

$$\frac{\delta}{1-\delta}(U_S^{NR} - U_S^{N}) \geq U_S^{ND}. \tag{SDE^{NR}}$$

[35] An examination of relational contracting when first-best is not attainable is available upon request.

If the seller reneges, he will not get any bonus from the buyer and the best he can do is to choose $e^{ND} = 0$. As he saves $g(e^{NR})$, but he relinquishes β^{NR}, the above inequality can be rewritten as:

$$\frac{\delta}{1-\delta}(U_S^{NR} - U_S^N) \geq g(e^{NR}) - \beta^{NR}.$$

The exact values of p^{NR} and β^{NR} are ultimately determined by the parties' bargaining power as well as the level of investment and contract specification that are implemented through relational contracting. Depending on the distribution of the bargaining power the price and the bonus can be used to provide incentives for investment and specification as well as to split surplus from the relationship. For the current purposes, what matters is that the two conditions can be combined in a single dynamic-enforcement constraint (DE), as shown by Levin (2003):

$$\frac{\delta}{1-\delta}(\underbrace{(U_B^{NR} + U_S^{NR})}_{W^{NR}} - \underbrace{(U_B^N + U_S^N)}_{W^N}) \geq g(e^{NR}). \qquad (DE^{NR})$$

The term in the round brackets in the LHS of the above constraint represents the overall per-period surplus brought about by relational contracting. This is given by the difference between the per-period welfare achievable under relational contracting, W^{NR}, and that which is achieved with spot transactions only, W^N, that we can call the overall fallback position. The RHS of DE^{NR} is the overall spot gain from reneging, which coincides with the seller's avoidance of the cost associated with the agreed-upon investment. Note that the bonus does not enter the above constraint, since it is a mere transfer between the buyer and the seller.

The optimal investment e^{NR} and contract specification s^{NR} maximize the expected social surplus, which is:

$$W^{NR} = v - \left[1 - \frac{s^{NR} + e^{NR}}{2}\right] h - g(e^{NR}) - k(s^{NR}), \qquad (20)$$

subject to (DE^{NR}). The following lemma determines the minimum level of the discount factor which ensures that $e^{NR} = e^*$ and $s^{NR} = s^*$.

Lemma 1. *When courts can only verify transfers, relational contracting induces the buyer's optimal specification of the design and the optimal seller's cooperative investment if and only if:*

$$\delta \geq \delta^{NR} \equiv \frac{g(e^*)}{h\left(\frac{s^* - s^N}{2} + \frac{e^*}{2}\right) - [k(s^*) - k(s^N)]}, \qquad (21)$$

and δ^{NR} *is increasing in* α

The higher the buyer's bargaining power, the higher the minimum level of the discount factor δ above which the parties can sustain the optimal specification of the design and the optimal cooperative investment, δ^{NR}. To understand why, recall that the higher α the larger the surplus associated with spot contracts, because the buyer is more motivated to better specify the characteristics of the good. In particular, when the buyer can appropriate all the gains from trade, the specification is first-best even if the relationship is not repeated. However, when the relationship is repeated, a higher α makes it more difficult to sustain a welfare-enhancing relational contract, since it reduces the surplus the parties can achieve by following through on their promises.

5.2 Verifiable Design Failure

When courts assign liability for a design failure, the per-period set of actions is enriched by the possibility for the buyer to sue 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.

The approach followed by courts to assign liability affects parties' temptation to renege in two ways: It determines what each party can gain by deviating in the current period, namely, the spot gain from reneging, and the parties' payoff if they revert to spot contracts thereafter, namely their fallback positions. Therefore, the two approaches entail different reneging incentives and the purpose of this subsection is to compare them to determine which one can more easily sustain first-best cooperative investment and contract specification. I refer to the actions that can be sustained with relational contracting under the formal authority and the real authority regimes with the superscripts FR and RR, respectively. To determine whether optimal relational contracting can be implemented under both regimes, the maximum temptation to renege must be contemplated (see Levin, 2003; Baker et al., 2002).

I start by characterizing the constraints that must be imposed in a regime of formal authority to implement an efficiency-enhancing relational contract. In stage 3, after observing a design failure, the buyer is willing to pay the promised bonus β^{FR} and to relinquish to sue the seller and collect damages if and only if:

$$\frac{\delta}{1-\delta}[U_B^{FR} - U_B^{F}] \geq U_B^{FD} = \beta^{FR} + \tilde{h}. \qquad (BDE^{FR})$$

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

$$\frac{\delta}{1-\delta}[U_S^{FR} - U_S^{F}] \geq U_S^{FD}, \qquad (SDE^{FR})$$

where U_S^{FD} represents the payoff the seller gets in the current period by deviating. This is given by:

$$U_S^{FD} = g(e^{FR}) - \beta^{FR} - \left(1 - \frac{s^{FR} + e^{FD}}{2}\right)\tilde{h} - g(e^{FD}). \tag{22}$$

To see why, consider that if the seller deviates, the buyer will withhold the promised bonus, β^{FR}, and sue the seller whenever there is a design failure. The seller saves the agreed-upon investment cost $g(e^{FR})$, but he will be willing to make some investment anyway so as to reduce the probability of failure. In particular, e^{FD} is determined by the following equation, which is derived from the first-order condition of (22):

$$g'(e^{FD}) = \frac{\tilde{h}}{2} = g'(e^F). \tag{23}$$

The cooperative investment the seller would make if he decided to deviate would be the same as e^F, namely, it would be independent of s^{FR} and would fall short of first-best only if $\tilde{h} < h$. Like before, the exact values of the price and the informal bonus critically depend on the implemented investment and specification as well as on the bargaining power allocation which determines how the surplus from relational contracting is distributed between the parties. Regardless, the parties' dynamic-enforcement constraints can be combined in a single condition:

$$\frac{\delta}{1-\delta}(\underbrace{(U_B^{FR} + U_S^{FR})}_{W^{FR}} - \underbrace{(U_B^F + U_S^F)}_{W^F}) \geq [g(e^{FR}) - g(e^{FD})] + \frac{s^{FR} + e^{FD}}{2}\tilde{h}. \tag{DE^{FR}}$$

Consider now the real-authority regime. To determine the buyer's spot gain from deviation in this alternative setting, UB^{RD}, I make the assumption that the parties are aware of how the court will rule if the design turns out to be defective when deciding whether or not to pay the bonus. Therefore, in stage 3, after observing a design failure that a court would attribute to the seller's negligence, the buyer is willing to pay the promised bonus, β^{RR}, and to relinquish to sue the seller and collect damages if and only if:

$$\frac{\delta}{1-\delta}[U_B^{RR} - U_B^R] \geq U_B^{RD} = \beta^{RR} + \tilde{h}. \tag{BDE^{RR}}$$

The right-hand side of the buyer's dynamic-enforcement constraint looks very similar to that of the formal-authority regime. This is due to the assumption that the parties know against whom the court will rule after a design failure.[36] The seller's dynamic-enforcement constraint under the real-authority regime is given by:

$$\frac{\delta}{1-\delta}[U_S^{RR} - U_S^R] \geq U_S^{RD}. \tag{SDE^{RR}}$$

[36]Later, I will comment on the repercussions of relaxing this assumption.

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

$$U_S^{RD} = g(e^{RR}) - \beta^{RR} - \left(1 - \frac{s^{RR} + e^{RD}}{2}\right) [1 - \phi(s^{RR})]\tilde{h} - g(e^{RD}). \tag{24}$$

Under the real-authority regime, if the seller deviates, the buyer will bring a lawsuit and will be awarded damages only if the seller can be held liable for the defective design. Therefore, by deviating the seller relinquishes the bonus and saves the cost associated with the agreed-upon investment. He will still be willing to make some investment so as to reduce the probability of paying the damages to the buyer. In particular, the cooperative investment the seller would choose if he decided to renege on the relational contract would satisfy the following equation, which is obtained from the first-order condition of (24):

$$g'(e^{RD}) = [1 - \phi(s^{RR})]\frac{\tilde{h}}{2}.$$

The marginal cost of the seller's investment if he deviates (the LHS of the above equation) equates its marginal benefit given by the reduction in the probability of paying the damages (the RHS). Since courts are assumed to assign liability according to real authority, this marginal benefit is decreasing in the buyer's informally agreed-upon specification of the good. Combining BDE^{RR} and SDE^{RR}, the dynamic-enforcement constraint in the real-authority regime (DE^{RR}) is obtained:

$$\frac{\delta}{1-\delta}(W^{RR} - W^{R}) \geq [g(e^{RR}) - g(e^{RD})] + \left(1 - [1 - \frac{s^{RR} + e^{RD}}{2}][1 - \phi(s^{RR})]\right)\tilde{h}, \quad (DE^{RR})$$

where, $W^{RR} = U_B^{RR} + U_S^{RR}$ and $W^{R} = U_B^{R} + U_S^{R}$.

In both regimes, cooperative investment and contract specification under relational contracting will be chosen to maximize the expected joint surplus, under the respective dynamic-enforcement constraint. In the following proposition, I determine which approach followed by courts makes it easier to sustain first-best investment and specification:[37]

Proposition 4. *Let δ^{FR} and δ^{RR} denote the minimum levels of the discount factor above which e^* and s^* can be implemented under the formal-authority and the real-authority regimes, respectively. There exists $\hat{\alpha} \in (0, 1]$ such that $\forall \alpha \leq \hat{\alpha}$, it holds that $\delta^{FR} < \delta^{RR}$.*

The proposition highlights the main result of this section: While the real-authority regime is associated with (weakly) worse spot contracts than the formal authority regime and, as a result, higher gains from using relational contracting, it also entails a higher

[37]The characterization of the minimum discount factors above which optimal investment and specification can be achieved in the two regimes can be found in the proof of the proposition.

spot gain from reneging. This is due to the more severe punishment the seller faces right after under-investing when formal authority conveys liability for the soundness of the design. If the seller deviates from the relational contract, the buyer will be willing to sue him if a design failure occurs. However, while the seller is sure to pay damages in a formal-authority regime, he may not be held liable by a court in a real-authority regime, which blunts the expected spot punishment he faces by unilaterally deviating.

It is also worth noting that the spot gains from reneging are not affected by the bargaining power distribution, whereas the fallback positions are. In particular, when $\alpha = 0$, the overall fallback position is the same in both regimes, i.e. $W^R(\alpha = 0) = W^F(\alpha = 0)$. As a result, when the seller captures the entire surplus from trade, a regime of formal authority always requires a lower degree of patience than a regime of real authority to sustain optimal relational contracting. Welfare achievable with spot transaction is increasing in α and, as shown in Corollary 1, $W^F > W^R$ whenever $\alpha > 0$. Therefore, when the buyer appropriates some benefit from trade, the surplus that can be achieved with relational contracting is higher when courts assign liability according to real authority. Yet, this may not be enough to offset the higher spot gain from reneging that this regime involves. This can also be shown graphically: Figure 3 illustrates the relationship existing between α and the cutoff values of δ above which first-best investment and specification can be achieved in the two regimes. For values of $\alpha \leq \hat{\alpha}$, the function δ^{RR}, colored in blue, lies above δ^{FR}, colored in red.[38] Furthermore, if parties reverted to no trade after a deviation and their outside option were regime invariant, then implementing first-best specification and investment would always require a lower level of δ in a regime of formal authority than in one of real authority.

In light of the above, it is possible to conclude that the courts' approach to assign liability according to real authority does not facilitate relational contracting. An exception occurs when the buyer has a sufficiently high bargaining power, as it may be the case when competitive procedures are held to select the seller among several bidders.

Note that the assumption that the buyer knows with certainty how the court will rule when she decides on whether or not to bring the lawsuit in a real-authority regime is not crucial for the results. First, one may assume that in stage 3 the buyer can expect to be awarded $\tilde{h}$ with some probability. As long as this probability is not too small, the spot gain from reneging continues to be larger under this regime than under formal authority. More importantly, the probability of recovering damages may depend on the type of flaw and it stands to reason that in some instances there is no ambiguity about how the court will rule ex-post. In other words, in some instances the fact that the seller's negligence

[38] The following values were taken to draw Figure 3: $h = 4$, $\tilde{h} = 2$, $g(e) = 2e^2$, $k(s) = 2s^2$, $\phi(s) = s$.

caused the design failure may be apparent. Since the maximum temptation to renege must be considered, then the BDE^{RR} constraint that is reported is necessary to sustain a relational contract in the real-authority regime.

This section has shown how relational contracting can help ensure efficient investment and contract specification provided that the parties are patient enough, i.e., δ 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 contracts to 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. In a different framework, Kvaløy and Olsen (2009) also find that relational contracting can cause contracts to be more incomplete. In contrast, in the present setting, when parties can turn to courts for a design failure and only spot transactions 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, since there is no need to strategically under-specify the good to spur the seller's cooperative investment. Therefore, a self-enforcing relational contract may actually lead to a more complete contract and this causal relationship has implications for empirical work.

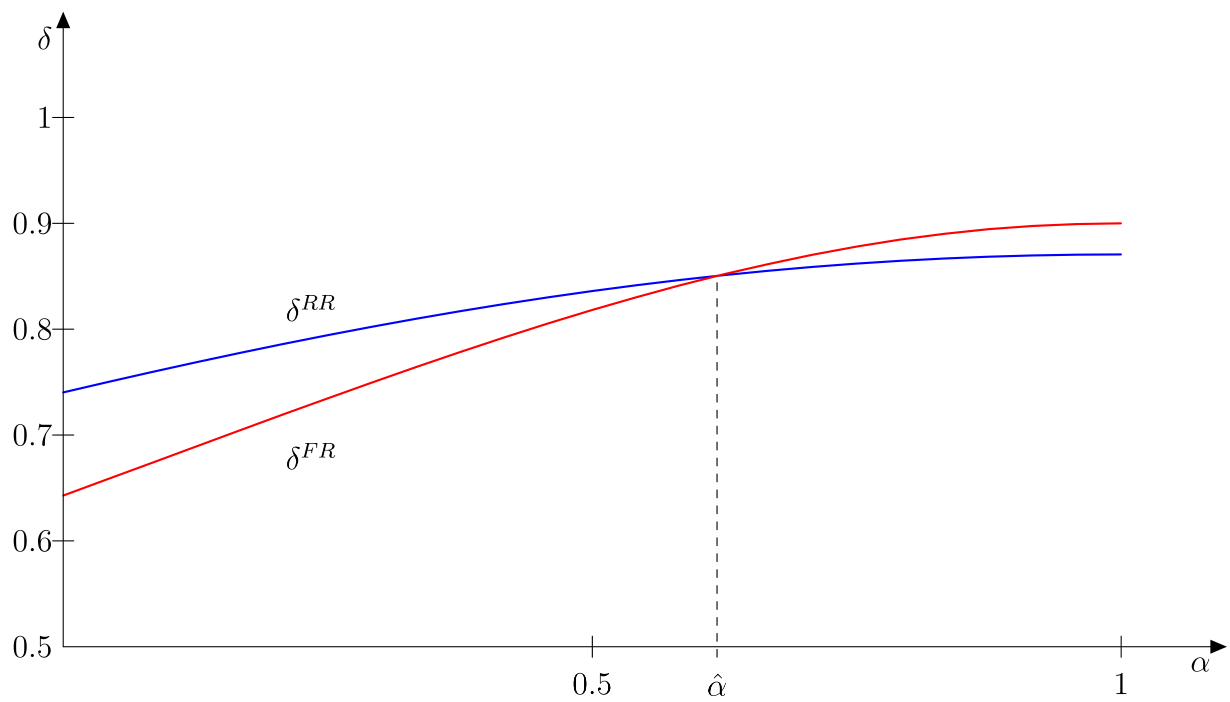


Figure 3: Relationship between α and δ^{FR} and δ^{RR}.

6 Extensions

In this section, I relax some assumptions and I analyze different variants of the baseline model to show the robustness of the results. Specifically, in Section 6.1 I examine an alternative legal remedy for breach of contract, liquidated damages; in Section 6.2 I allow for complementarity and substitutability between seller's cooperative investment and buyer's good specification; in Section 6.3 I develop an alternative modeling formulation in which only the seller's investment reduces the probability of a design failure, whereas the buyer's specification increases the value of the good.

6.1 Liquidated Damages

The adoption of the *liquidated damages* rule can ensure efficient specification and investment, even if liability for a design failure is allocated according to real authority. Under liquidated damages, the buyer is awarded contractually-specified monetary damages if the court holds that she has been harmed. The contract signed in stage 1 by the parties 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:

$$U_S^L(e, s, D) = -\left(1 - \frac{e+s}{2}\right)[1-\phi(s)]D - g(e). \tag{25}$$

The seller's best response of e given both s and D, denoted e^L, is:

$$g'(e^L(s, D)) = [1-\phi(s)]\frac{D}{2}. \tag{26}$$

In stage 1, the buyer chooses s and D to maximize her utility:

$$U_B^L(s, D) = \alpha\left(v - \left[1 - \frac{s + e^L(s, D)}{2}\right]h - g(e^L(s, D))\right) - k(s). \tag{27}$$

Maximization yields:

$$k'(s^L) = \alpha\left(\frac{h}{2} + \left(\frac{h}{2} - g'(e^L)\right)\frac{\partial e^L}{\partial s}\right), \tag{28}$$

and

$$\left(\frac{h}{2} - g'(e^L)\right)\frac{\partial e^L}{\partial D} = 0. \tag{29}$$

From the implicit function theorem:

$$\frac{\partial e^L(s, D)}{\partial s} = -\frac{\phi'(s)D}{2g''(e^L)} < 0,$$

and

$$\frac{\partial e^L(s, D)}{\partial D} = \frac{1-\phi(s)}{2g''(e^L)} > 0.$$

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 $D^L = \frac{h}{1-\phi(s^L)}$.[39] 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 or award expectation damages but only consider the allocation of formal authority to determine liability. Put differently, at the equilibrium the buyer does not strategically under-specify the contract to spur the seller's investment.

Proposition 5. *Under liquidated damages, the buyer optimally specifies the good when* $\alpha = 1$*. There is the same under-specification of the good as when courts do not verify a design failure or when courts award expectation damages and assign liability according to formal authority when* $\alpha < 1$*. 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 courts only take into account the formal allocation of authority to determine liability. Both rules require that a court 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. 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.

6.2 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. In some occurrences this assumption may be suitable: For instance, if the parties focus on different aspects of the design and, as a result, their tasks do not overlap. More importantly, it has the merit of highlighting how the approach followed by courts

[39] The fact that the optimal liquidated damages clause is over-compensatory ex-post is well known in the law and economics literature (see Ganglmair, 2017 and references therein).

itself might make the parties' optimal investment choices interdependent, thereby providing a very neat result on the implications of the real-authority regime for investment and specification incentives.

Arguably, in some instances an increase in the buyer's specification may make the seller's job of ensuring that the design of the good is adequate harder or easier. For example, suppose that the parties avail themselves of an initial design and the buyer's specification of the good determines the probability that such initial design is adequate and yields utility v. With probability $1 - s$ the initial design is incorrect and only yields $v - h$. At stage 2, the seller knows that his cooperative investment will reduce the probability of failure only if the initial design is not adequate. Welfare is $W(s, e) = v - (1-s)(1-e)h - k(s) - g(e)$ and note that $q(s, e) = s + e - se$, with $q_{es} = q_{se} = -1 < 0$. This formulation bears some resemblance to that developed by Tirole (2009), even though there are some notable differences in the set-ups.

An alternative formulation is one in which the buyer's specification of the good is essential to reduce the probability of failure and the seller's investment is more valuable when the design is more comprehensive, e.g. $q(s, e) = \frac{s(1+e)}{2}$, where $q_{es} = q_{se} = 1/2 > 0$.

In either case, even if courts assign liability for a defective design according to formal authority, when deciding the specification of the good the buyer must take into account how the seller's choice of e will be affected by her choice of s. Although the analysis becomes more cumbersome, some of the main results continue to arise. Namely, the buyer continues to have an incentive to strategically reduce the completeness of the contract to motivate the seller's investment if liability is assigned according to real authority.

Below I consider a more general setting where 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.[40] I further assume that it is prohibitively costly to avoid a design failure with certainty.

Denote by e^* and s^* the first-best level of seller's cooperative investment and buyer's specification, respectively:[41]

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

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

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

[41] The first-best investment and specification are derived in the proof of Lemma 2.

Non-verifiable design failure. 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 complementarity between e and s. The buyer's specification of the contract is then:

$$k'(s^N) = \alpha q_s(s^N, 0)h. \tag{30}$$

Differently from 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 α is near 1 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 $\alpha = 1$ it holds that $s^N < s^*$.

Lemma 2. *When courts can only verify transfers,*

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

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

Verifiable design failure and real authority. Suppose now that a design failure is verifiable and begin by considering the real-authority regime. 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:

$$g'(e^R) = q_e(s^R, e^R)[1 - \phi(s^R)]\tilde{h}; \tag{31}$$

$$k'(s^R) = \max\left\{0, \alpha\left(q_s(s^R, e^R)h + [q_e(s^R, e^R)h - g'(e^R)]\frac{\partial e^R(s)}{\partial s}\right)\right\}. \tag{32}$$

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 be non-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., $s^R < s^N$. The reason is twofold: First, since 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, the buyer finds it profitable to reduce specification so as to encourage the seller's investment, i.e., $\frac{\partial e^R(s)}{\partial s} < 0$. A less complete contract induces the seller to invest more because it increases both the likelihood that the seller will be held accountable for a design failure and the seller's return to the cooperative investment. The former effect arises even when $q(s,e)$ is additively separable in s and e and is what has been defined as *strategic*, since it is engendered by the way courts assign liability for a defective design. The latter effect is specifically due to the substitutability assumption.

A parallel argument explains why contract completeness can actually increase as compared to when courts do not assign liability for a design failure when investment and specification are complements. First, 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 $e > 0$. Second, it may be the case that $\frac{\partial e^R(s)}{\partial s} > 0$. While the buyer can strategically spur the seller's cooperative investment by reducing specification, the seller's return to the cooperative investment is higher when the contract is more complete, namely there is a *complementarity effect.* The contract specification is more complete if the complementarity effect is strong enough as to outweigh the strategic effect which calls for an under-specification.

Lemma 3. *In a real-authority regime,*

(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. $s^R < s^N$*;*

(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:

$$\frac{q_{es}(s^R, e^R)}{q_e(s^R, e^R)} < \frac{\phi'(s^R)}{1-\phi(s^R)}. \tag{33}$$

The lemma characterizes a necessary condition for the contract to be more incomplete when the design failure can be verified. If inequality (33) holds, at the equilibrium a marginal increase in s affects more strongly the probability that the buyer will be held accountable for the design failure, given that it was not accountable with specification s^R (i.e., the hazard rate), than the marginal impact that e has on the probability that a failure will occur (the left-hand side of the inequality). 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. On the contrary, if the complementarity existing between specification and investment is strong enough, this condition is not verified and the contract is more complete when courts assign liability for a design failure depending on the allocation of real authority than when a failure is unverifiable to a third party.

Verifiable design failure and formal authority. In the formal-authority regime, the seller chooses a positive level of cooperative investment at the equilibrium to reduce the probability of paying damages, i.e. $e^F > 0$. Despite the absence of a strategic effect, the buyer can find it profitable to write a more or less incomplete contract to spur the seller's cooperative investment. First-order conditions are:

$$g'(e^F) = q_e(s^F, e^F)\tilde{h};$$

$$k'(s^F) = \max\left\{0, \alpha\left(q_s(s^F, e^F)h + [q_e(s^F, e^F)h - g'(e^F)]\frac{\partial e^F(s)}{\partial s}\right)\right\}.$$

The buyer is willing to take into consideration how her marginal specification affects the equilibrium cooperative investment if damages are under-compensatory, that is, $\tilde{h} < h$, for otherwise the term $q_e(s^F, e^F)h - g'(e^F) = 0$. If investment and specification are substitutes, $\frac{\partial e^F(s)}{\partial s} < 0$, and $e^F > 0$. As a result, $s^F < s^N$. Comparison with the real-authority regime turns out to be more ambiguous. On the one hand, the buyer does not have an incentive to reduce specification to increase the seller's responsibility. At the same time, for the same level of s, the seller is more motivated to invest because he is always held accountable for defects. In turn, a higher expected investment induces the buyer to decrease specification because of substitutability.

If investment and specification are complements, $\frac{\partial e^F(s)}{\partial s} > 0$, and therefore it is always the case that $s^F > s^N$. Formal authority mitigates the under-investment problem and under-specification problem as compared to the case in which courts take into consideration the allocation of real authority if the complementarity effect is not too strong. This is because the strategic effect that arises in the real-authority regime magnifies the under-specification problem.

Lemma 4. *In a formal-authority regime,*

(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. $s^F < s^N$*;*

(iii) *if specification and investment are complements, the contract is more complete when the court can assign liability for a design failure than when it cannot, i.e., $s^F > s^N$, and when the court considers the allocation of real authority, i.e., $s^F > s^R$, if (33) holds.*

The comparison between the real-authority and formal-authority regimes become more cumbersome and ambiguous, especially when there is substitutability between investment and specification. The following proposition summarizes the main results of this section.

Proposition 6. *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 in the real-authority regime and is always higher in the formal-authority regime.*

The proposition highlights the robustness of our main results: A real-authority regime induces the buyer to strategically under-specify the contract so as to increase the ex-ante probability that the seller will be accountable for defects, thereby prompting a higher equilibrium cooperative investment.

Alternative assumptions concerning the relationship between the buyer's specification and the seller's investment offer different testable implications. In the presence of complementarity of independence, the model predicts that we should observe more specified designs in countries which adopt a formal-authority regime than in those which follow a real-authority approach. The empirical implication is more ambiguous if investment and specification are substitutes.

6.3 Alternative Modeling Approach

I now argue that an alternative modeling approach can be pursued to highlight how formal and real authority regimes differently affect contract specification and investment. Suppose that only the seller's investment reduces the probability of failure whereas the buyer's specification raises the value of the good and negatively affects the seller's cooperative investment cost. A more comprehensive specification of the good may make the good a better fit for the buyer's unique needs. At the same time, it may make more challenging, and hence more costly, for the seller to produce the good exactly according with the more complex specification provided by the buyer. In a regime of real authority, the court will take into consideration how much specified the good was to assign liability when the design is not adequate, thereby acknowledging the negative impact of specification on the seller's investment cost. This alternative modeling formulation bears some resemblance with the setup developed by Bajari and Tadelis (2001) and Tadelis (2002). Akin to these papers, a more complex project increases the cost of guaranteeing that the design is adequate with a given probability. Unlike them, I posit that (i) the buyer can choose the level of complexity of the project, which increases her valuation of the good, and (ii) can delegate to the seller the task of investing to decrease the probability that the design is inadequate.[42]

Specifically, assume that the buyer's valuation of the good is $V(s) = \bar{v} + v(s)$ with $v'(s) > 0$, $v''(s) \leq 0$, $v(0) = 0$, and $v'(0) = \infty$. The buyer chooses how much to specify the good at cost $k(s)$, with $k'(s) > 0$, $k''(s) > 0$, $k(0) = k'(0) = 0$.

The seller decides how much to invest to improve the quality of the design. The likelihood that the design is correct is $q(e)$ with $q'(e) > 0$, $q''(e) \leq 0$, $q(0) = 0$. Cooperative investment costs the seller $g(e, s)$, with $g_e(e, s) > 0$, $g_{ee}(e, s) > 0$, $g_s(e, s) > 0$, $g_{es}(e, s) = g_{se}(e, s) > 0$, $g(0, s) = g_e(0, s) = 0$ for all s.

Appendix B provides a formal analysis of this alternative set-up, whose results are very close to those presented for the case of substitutability between s and e in the initial set-up. When deciding the specification of the good, the buyer takes into account the negative effect of a larger s on the seller's investment cost. However, if the seller cannot be expected to invest because the court will never compel him to pay damages in case of failure, the buyer will provide a richer specification of the good than in first best. When courts assign liability according to real authority, the seller will make some investment. Since damages may be under-compensatory and the court can rule that the buyer is actually accountable for the design failure, the seller's incentives to invest are dampened. The buyer will reduce the specification of the good so as to spur the seller's investment: A lower specification decreases the cost of ensuring that the design is correct with a given probability and increases the ex-ante probability that the seller will be accountable for a design failure. Under formal authority, the buyer may be willing to distort her specification decision to stimulate the seller's investment only if damages are under-compensatory and she does not hold all the bargaining power.

[42] This set-up is also compatible with the model of project complexity put forward by Bajari and Tadelis (2001), wherein a more complex project is characterized by a larger number of states that can occur and the cost of specifying a state of nature as well as the probability that states occur are such that it is more costly to ensure that the design is adequate.

7 Conclusions

The court's ability to verify a defective design can motivate the seller to make a cooperative specific investment so as to reduce the probability of being obliged to pay damages. However, the paper has shown that the court's approach of assigning liability for a defective design according to real authority may induce the buyer to strategically under-specify the characteristics of the good. A lower degree of contract completeness decreases the likelihood that the buyer will be held liable for a design failure, thereby prompting the seller to invest more.

The implications of this court's approach may even be more far-reaching as it may stifle innovation and competition. To illustrate the first 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 a seller's specific investment in R&D. The buyer might decide to use the standard design anticipating that what she could achieve by choosing the customized alternative 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 sub-optimal. As for the latter point, the surplus that can be appropriated by a seller is lower than in a regime where liability can be effectively allocated to one of the parties with a formal contract. Since expected profits are lower, prospective firms would be reluctant to bear some sunk costs to enter the market.

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 as a way to shift design risk from the owner to the contractor.[43] In fact, in those countries where courts review the owner's specification to assign liability for a design failure, design risk can be shifted only by delegating real and not merely formal authority.

The paper has also explored whether this court's approach could prove superior when there is repeated interaction, so that the trading parties can make use of relational contracts. Because of a lower level of surplus achievable with spot transactions, the benefits of relational agreements are greater in a real-authority regime than in one of formal authority. However, I have highlighted that the former regime entails a more tempting spot gain from breaching the informal agreement than the latter: Should the seller decide to back out by under-investing, he will have to pay damages with a lower probability in the regime of real authority. As a result, sustaining a superior relational contract is often

[43] 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*").

easier in a regime of formal authority. Hence, in contrast with the hypothesis that courts may attempt to promote economic efficiency, these findings show that the approach followed by courts in some countries, such as the United States, cannot easily be justified on efficiency grounds: Irrespective of whether efficiency in spot or relational transactions is considered, a formal-authority regime tends to dominate one based on real authority.[44] Then, the purpose of this latter approach must be sought in the court's willingness to assign liability in a way which is deemed just ex-post, disregarding its ex-ante effects on specification and investment.[45]

[44] Note that these findings do not necessarily contradict the efficiency theory of common law, since this does not argue that every doctrine or decision will be efficient (see Posner, 2003).

[45] For an interesting discussion of the possible conflict between the objectives of creating incentives for future conduct and of pursuing fairness in adjudicating legal disputes, see the treatment of ex-ante and ex-post perspectives in Easterbrook (1984).

Appendix A

Proof of Proposition 3

To see that the buyer under-invests in the specification of the good, consider that it is possible to obtain $\frac{\partial e^R(s)}{\partial s}$ 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:

$$\frac{\partial e^R(s)}{\partial s} = -\frac{\phi'(s)\frac{\tilde{h}}{2}}{g''(e^R(s))}$$

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 $\frac{\partial e^R(s)}{\partial s} < 0$.

Moreover,

$$\frac{h}{2} - g'(e^R) > 0$$

since

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

and, as a result,

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

which can be rewritten as

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

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

$$k'(s^R) = \alpha \left(\frac{h}{2} + \underbrace{\left[\frac{h}{2} - g'(e^R) \right]}_{>0} \underbrace{\frac{\partial e^R}{\partial s}}_{<0} \right) < k'(s^N)$$

If $h/2 > -[h/2 - g'(e^R)](\partial e^R)/(\partial s)$ and 0 otherwise.

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

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

where

$$\frac{\partial^2 e^R}{\partial s^2} = -\frac{\phi''(s)\frac{\tilde{h}}{2}g''(e^R(s)) - \phi'(s)\frac{\tilde{h}}{2}g'''(e^R(s))\frac{\partial e^R(s)}{\partial s}}{(-g''(e^R(s)))^2}$$

is non-positive. To see this, note that the denominator is positive and, as a result, the sign of $\frac{\partial^2 e^R}{\partial s^2}$ 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 Corollary 1

I need to show that $W^F \geq W^R$ for all $\alpha \in [0,1]$ and strictly so for $\alpha > 0$. To see this, note that this inequality holds if and only if:

$$v - \left[1 - \frac{s^F + e^F}{2}\right] h - k(s^F) - g(e^F) \geq v - \left[1 - \frac{s^R + e^R}{2}\right] h - k(s^R) - g(e^R)$$

that is:

$$\frac{s^F + e^F}{2} h - k(s^F) - g(e^F) \geq \frac{s^R + e^R}{2} h - k(s^R) - g(e^R)$$

If $\alpha = 0$, $s^R = s^F = 0$, and $e^R = e^F$ and they are determined by:

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

Hence, $W^R = W^F$ when $\alpha = 0$. Now, assume that $\alpha < 1$. Note that:

$$\frac{s^F}{2} h - k(s^F) > \frac{s^R}{2} h - k(s^R)$$

Suppose, conversely, that:

$$\frac{s^R}{2} h - k(s^R) \geq \frac{s^F}{2} h - k(s^F)$$

multiply each side by α:

$$\alpha \frac{s^R}{2} h - k(s^R) + (1-\alpha) k(s^R) \geq \alpha \frac{s^F}{2} h - k(s^F) + (1-\alpha) k(s^F)$$

However, note that: (i) $(1-\alpha)k(s^F) > (1-\alpha)k(s^R)$ for any $\alpha \in (0,1)$ because $k(\cdot)$ is an increasing function of s and $s^F > s^R$, and $(1-\alpha)k(s^F) = (1-\alpha)k(s^R)$ for $\alpha = 1$; (ii)

$$\alpha \frac{s^R}{2} h - k(s^R) < \alpha \frac{s^F}{2} h - k(s^F)$$

because $s^F = \arg\max_{s \in [0,1]} \alpha \frac{s}{2} h - k(s)$ - whereas $s^R = \arg\max_{s \in [0,1]} \alpha \left[\frac{s + e^R(s)}{2} h - g(e^R(s))\right] - k(s)$. This leads to a contradiction.

In a similar fashion, it is possible to show that:

$$\frac{e^F}{2} h - g(e^F) > \frac{e^R}{2} h - g(e^R)$$

Suppose, conversely, that:

$$\frac{e^R}{2} h - g(e^R) \geq \frac{e^F}{2} h - g(e^F)$$

multiply each side by $\frac{\tilde{h}}{h}$:

$$\frac{e^R}{2} \tilde{h} - g(e^R) \frac{\tilde{h}}{h} \geq \frac{e^F}{2} \tilde{h} - g(e^F) \frac{\tilde{h}}{h}$$

This can be rewritten as:

$$\frac{e^R}{2}\tilde{h} - g(e^R) + \frac{h-\tilde{h}}{h}g(e^R) \geq \frac{e^F}{2}\tilde{h} - g(e^F) + \frac{h-\tilde{h}}{h}g(e^F)$$

Now note that: (i) $\frac{h-\tilde{h}}{h}g(e^F) > \frac{h-\tilde{h}}{h}g(e^R)$ because $g(\cdot)$ is an increasing function and $e^F > e^R$ for all $\alpha > 0$ and (ii) it holds that:

$$\frac{e^R}{2}\tilde{h} - g(e^R) < \frac{e^F}{2}\tilde{h} - g(e^F)$$

because $e^F = \arg\max_{e\in[0,1]} \frac{e}{2}\tilde{h} - g(e)$ - whereas $e^R = \arg\max_{e\in[0,1]} \frac{e}{2}(1-\phi(s^R))\tilde{h} - g(e)$. This leads to a contradiction.

□

Proof of Remark 1

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

$$F_1(e,s,\tilde{h}) = 0 \Leftrightarrow (1-\phi(s))\frac{\tilde{h}}{2} - g'(e) = 0$$
$$F_2(e,s,\tilde{h}) = 0 \Leftrightarrow \alpha\left(\frac{h}{2} - \left[\frac{h}{2} - g'(e)\right]\frac{\phi'(s)\tilde{h}}{2g''(e)}\right) - k'(s) = 0$$

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

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

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

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

which is always strictly positive. Indeed, the buyer's utility function U_B^R is strictly concave.

We can thus use the Cramer's rule to determine the effect of a 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:

$$\frac{\partial e^R}{\partial \tilde{h}} = \frac{\begin{vmatrix} -\frac{1-\phi(s)}{2} & -\phi'(s)\frac{\tilde{h}}{2} \\ \alpha(\frac{h}{2} - g'(e))\frac{\phi'(s)}{2g''(e)} & -\alpha(\frac{h}{2} - g'(e))\frac{\phi''(s)\tilde{h}}{2g''(e)} - k''(s) \end{vmatrix}}{\begin{vmatrix} -g''(e) & -\phi'(s)\frac{\tilde{h}}{2} \\ \alpha\left(\frac{\phi'(s)\tilde{h}}{2} + (\frac{h}{2} - g'(e))\frac{\phi'(s)\tilde{h}g'''(e)}{2(g''(e))^2}\right) & -\alpha(\frac{h}{2} - g'(e))\frac{\phi''(s)\tilde{h}}{2g''(e)} - k''(s) \end{vmatrix}}$$

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:

$$\frac{1-\phi(s)}{2}\alpha(\frac{h}{2}-g'(e))\frac{\phi''(s)\tilde{h}}{2g''(e)}+\frac{1-\phi(s)}{2}k''(s)$$
$$+\phi'(s)\frac{\tilde{h}}{2}\alpha(\frac{h}{2}-g'(e))\frac{\phi'(s)}{2g''(e)}$$

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

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

$$\frac{\partial s^R}{\partial \tilde{h}}=\frac{\begin{vmatrix} -g''(e) & -\frac{1-\phi(s)}{2} \\ \alpha\left(\frac{\phi'(s)\tilde{h}}{2}+(\frac{h}{2}-g'(e))\frac{\phi'(s)\tilde{h}g'''(e)}{2(g''(e))^2}\right) & \alpha(\frac{h}{2}-g'(e))\frac{\phi'(s)}{2g''(e)}\end{vmatrix}}{\begin{vmatrix} -g''(e) & -\phi'(s)\frac{\tilde{h}}{2} \\ \alpha)\left(\frac{\phi'(s)\tilde{h}}{2}+(\frac{h}{2}-g'(e))\frac{\phi'(s)\tilde{h}g'''(e)}{2(g''(e))^2}\right) & -\alpha(\frac{h}{2}-g'(e))\frac{\phi''(s)\tilde{h}}{2g''(e)}-k''(s)\end{vmatrix}}$$

Again, since the denominator is positive, the effect is positive if and only if the numerator is positive:

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

This is positive only if:

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

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

$$\frac{1-\phi(s)}{2}\tilde{h}>(\frac{h}{2}-g'(e))$$

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^R if $\tilde{h}$ is large enough.

□

Proof of Lemma 1

To determine W^N recall that $e^N=0$, whereas $s^N(\alpha)$ is strictly increasing in α with $s^N(0)=0$, and $s^N(1)=s^*$. Hence,

$$W^N(\alpha)=v-\left(1-\frac{s^N(\alpha)}{2}\right)h-k(s^N(\alpha))$$

The dynamic-enforcement constraint can be rewritten as:

$$\frac{\delta}{1-\delta}\left[\left(\frac{s^{NR}-s^{N}(\alpha)}{2}+\frac{e^{NR}}{2}\right)h-[k(s^{NR})-k(s^{N}(\alpha))]-g(e^{NR})\right]\geq g(e^{NR}) \qquad \text{(DE)}$$

from which it is possible to recover (21) by setting $e^{NR}=e^*$ and $s^{NR}=s^*$. Note that as α increases, W^N increases and the wedge between W^{NR} and W^N shrinks, thereby increasing δ^N and making it more unlikely that the parties will be able to implement both e^* and s^*. Specifically,

$$\delta^{NR}(\alpha)\in\left[\frac{g(e^*)}{h\frac{s^*+e^*}{2}-k(s^*)},\frac{g(e^*)}{h\frac{e^*}{2}}\right]$$

□

Proof of Proposition 4

First, I derive δ^{FR} and δ^{RR}. Under the formal-authority regime, the optimal investment and specification maximize the expected joint surplus, which is:

$$W^{FR}=v-\left[1-\frac{s^{FR}+e^{FR}}{2}\right]h-g(e^{FR})-k(s^{FR}) \qquad \text{(A1)}$$

subject to (DE^{FR}). The minimum level of the discount factor above which it is possible to implement $e^{FR}=e^*$ and $s^{FR}=s^*$ is denoted δ^{FR} and is obtained by making (DE^{FR}) bind:

$$\delta^{FR}\equiv\frac{g(e^*)-g(e^{FD})+\frac{s^*+e^{FD}}{2}\tilde{h}}{\left(\frac{s^*+e^*}{2}-\frac{s^F+e^F}{2}\right)h-[(k(s^*)-k(s^F))]+\frac{s^*+e^{FD}}{2}\tilde{h}} \qquad \text{(A2)}$$

which is increasing in α.

Under the real-authority regime, the optimal investment and specification maximize the expected joint surplus, which is:

$$W^{RR}=v-\left[1-\frac{s^{RR}+e^{RR}}{2}\right]h-g(e^{RR})-k(s^{RR}) \qquad \text{(A3)}$$

subject to (DE^{RR}). The minimum level of the discount factor above which it is possible to implement $e^{RR}=e^*$ and $s^{RR}=s^*$ is denoted δ^{RR}, and is obtained by making (DE^{RR}) hold with equality:

$$\delta^{RR}\equiv\frac{g(e^*)-g(e^{RD})+\left(1-[1-\frac{s^*+e^{RD}}{2}][1-\phi(s^*)]\right)\tilde{h}}{\left(\frac{s^*+e^*}{2}-\frac{s^R+e^R}{2}\right)h-[(k(s^*)-k(s^R))]+g(e^R)-g(e^{RD})+\left(1-[1-\frac{s^*+e^{RD}}{2}][1-\phi(s^*)]\right)\tilde{h}} \qquad \text{(A4)}$$

Now, compare the LHSs of (DE^{RR}) and (DE^{FR}) when first-best is achieved through relational contracting. The left-hand side of the former is larger because there is more to gain with relational contracting under the real-authority regime than under the formal-authority regime:

$$\frac{\delta}{1-\delta}[W^* - W^R] \geq \frac{\delta}{1-\delta}[W^* - W^F]$$

for all $\alpha \in [0, 1]$ and strictly so for $\alpha > 0$. Note that this inequality holds if and only if $W^F \geq W^R$ and this is always the case for all α and strictly so for $\alpha > 0$.

Compare the RHSs of (DE^{RR}) and (DE^{FR}), that is, the one-shot gain from breaching the relational contract. Again, consider the constraints when first-best is achieved through relational contracting. The right-hand side of (DE^{RR}) is larger than the right-hand side of (DE^{FR}) if and only if:

$$\tilde{h} - \left(1 - \frac{s^* + e^{RD}}{2}\right)(1-\phi(s^*))\tilde{h} - g(e^{RD}) + g(e^*) > \tilde{h} - \left(1 - \frac{s^* + e^F}{2}\right)\tilde{h} - g(e^F) + g(e^*)$$

namely, if and only if:

$$-\left(1 - \frac{s^* + e^{RD}}{2}\right)(1-\phi(s^*))\tilde{h} - g(e^{RD}) > -\left(1 - \frac{s^* + e^F}{2}\right)\tilde{h} - g(e^F)$$

which is always the case, because (i)

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

for any $e \in [0, 1]$, since $s^* > 0$ and (ii) e^{RD} is the unique maximizer of the left-hand side.

Note that the RHSs do not depend on α. Nor do W^*. Therefore, it is possible to conclude that at $\alpha = 0$, $W^F = W^R$ and, as a result, $W^* - W^F = W^* - W^R$. Since the one-shot gain from breaching the contract is always lower under the formal-authority regime, it follows that $\delta^{FR} < \delta^{RR}$ at $\alpha = 0$. For any $\alpha > 0$, $W^R(\alpha) < W^F(\alpha)$. Since W^R and W^F are both continuous in α over the interval $[0, 1]$ and so are δ^{RR} and δ^{FR}, there exists $\hat{\alpha} \in (0, 1]$ such that for any $\alpha \leq \hat{\alpha}$ it holds that $\delta^{FR}(\alpha) < \delta^{RR}(\alpha)$. Note that there might not be an admissible level of α for which $\delta^{FR}(\alpha) > \delta^{RR}(\alpha)$.

□

Proof of Proposition 5

Recall that

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

To satisfy (29), buyer must set:

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

By doing so, (28) becomes:

$$k'(s^L) = \alpha\frac{h}{2}$$

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

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

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

$$-\underbrace{g''(e)\left(\frac{\partial e}{\partial s}\right)^2}_{>0} - \underbrace{\frac{k''(s)}{\alpha}}_{>0} < 0$$

$$-\underbrace{g''(e)\left(\frac{\partial e}{\partial D}\right)^2}_{>0} < 0$$

and (ii) the determinant of the Hessian matrix is positive:

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

□

Proof of Lemma 2

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

Welfare is given by:

$$W(s,e) = v - [1 - q(s,e)]h - k(s) - g(e) \tag{A5}$$

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

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

It follows that:

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

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

$$s^* \equiv \arg\min_{s \geq 0}[1 - q(s, e^*(s))]h + k(s) + g(e^*(s)) \tag{A7}$$

It follows that:[46]

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

[46]Note that the derivative of (A7) with respect to s yields:

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

the terms $g'(e^*(s))$ and $q_e(s, e^*(s))$ cancel each other out. It is a simple application of the Envelope Theorem.

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

When courts are unable to verify a design failure, the seller chooses e to maximize his utility in stage 2:

$$U_S^N = -g(e)$$

As a result, $e^N = 0$ irrespective of whether investment and specification are substitutes or complements. Buyer's chosen contractual specification satisfies:

$$k'(s^N) = \alpha q_s(s^N, 0)h$$

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 α. Let:

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

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

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

and when $\alpha = 1$:

$$G^N(1) = M > k'(s^*) = q_s(s^*, e^*)$$

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

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

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

□

Proof of Lemma 3

In stage 2, the seller faces this problem:

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

The seller's best response of e given s yields:

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

The price satisfies the following:

$$\begin{aligned} p^R &= g(e^R(s)) + [1 - q(s, e^R(s))][1 - \phi(s)]\tilde{h} \\ &\quad + (1 - \alpha)(v - [1 - q(s, e^R(s))]h - g(e^R(s))) \end{aligned}$$

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

$$U_B^R = \alpha(v - g(e^R(s)) - [1 - q(s, e^R(s))]h) - k(s)$$

which I assume to be strictly concave in s to guarantee a unique equilibrium specification level.[47] Maximization yields (focusing on the case in which $s^R > 0$):

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

Irrespective of whether the investments are complements or substitutes

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

To see this, consider that $g'(e^R) = q_e(s^R, e^R)[1 - \phi(s^R)]\tilde{h}$ and, as a result,

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

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

$$\frac{\partial e^R(s)}{\partial s} = -\frac{(q_{es}(s, e^R)[1 - \phi(s)] - q_e(s, e^R)\phi'(s))\tilde{h}}{q_{ee}(s, e^R)[1 - \phi(s)]\tilde{h} - g''(e^R(s))}$$

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 $\frac{\partial e^R(s)}{\partial s}$ coincides with that of the numerator.

If investments are substitutes, $q_{es} < 0$ and because $q_e(s, e^R)\phi'(s) > 0$ the numerator is negative. As a result, $k'(s^R) < \alpha q_s(s^R, e^R)h$. 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. $q_s(s, e^R) < q_s(s, e^N)$ for all finite s. Hence, it is possible to conclude that $s^R < s^N$.

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

$$\frac{q_{es}(s^R, e^R)}{q_e(s^R, e^R)} < \frac{\phi'(s^R)}{1 - \phi(s^R)}$$

However, this is just a necessary condition for the contract to be more incomplete when courts assign liability for a design failure (in the real-authority regime) than when they 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. $q_s(s, e^R) > q_s(s, e^N)$ for all finite s. □

[47] When $q(s, e)$ is submodular, this requires that $k(s)$ be sufficiently strictly convex.

Proof of Lemma 4

In stage 2, the seller faces this problem:

$$\max_{e\geq 0} \quad -[1-q(s,e)]\tilde{h} - g(e)$$

The seller's best response of e given s yields:

$$g'(e^F(s)) = q_e(s,e^F(s))\tilde{h}$$

The price the parties agree upon is the following:

$$\begin{aligned} p^F &= g(e^F(s)) + [1-q(s,e^F(s))]\tilde{h} \\ &\quad + (1-\alpha)(v - [1-q(s,e^F(s))]h - g(e^F(s))) \end{aligned}$$

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

$$U_B^F = \alpha(v - g(e^F(s)) - [1-q(s,e^F(s))]h) - k(s)$$

which I assume to be strictly concave in s to guarantee a unique equilibrium specification level.[48] Maximization yields (focusing on the case in which $s^F > 0$):

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

Irrespective of whether the investments are complements or substitutes

$$q_e(s^F,e^F)h - g'(e^F) = q_e(s^F,e^F)(h-\tilde{h}) > 0$$

for all $h > \tilde{h}$.

The sign of $\frac{\partial e^F(s)}{\partial s}$ is affected by the complementarity or substitutability between investments:

$$\frac{\partial e^F(s)}{\partial s} = -\frac{q_{es}(s,e^F(s))\tilde{h}}{q_{ee}(s,e^F(s))\tilde{h} - g''(e^F(s))}$$

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 $\frac{\partial e^F(s)}{\partial s}$ coincides with that of the numerator.

If investment and specification are substitutes, $q_{es} < 0$ and, as a result, the numerator is negative. Note that if $\tilde{h} = h$, then cooperative investment is above first-best if $\alpha < 1$ because contract specification would satisfy $k'(s^F) = \alpha q_s(s^F,e^F)h$ which is below first-best. If $\tilde{h} = h$ and $\alpha = 1$, then both contract specification and cooperative investments are first-best.

[48] When $q(s,e)$ is submodular this requires that $k(s)$ be sufficiently strictly convex.

If $\tilde{h} < h$, then $k'(s^F) < \alpha q_s(s^F, e^F)h$ and e^F can be above or below first-best. It continues to hold that $e^F > e^N = 0$ and, as a result, $s^F < s^N$.

Comparison with the real-authority regime is more ambiguous: With real authority, the buyer has an additional incentive to under-specify the contract, that of increasing the seller's responsibility. At the same time, for the same level of s, the seller is less motivated to invest because he may not be held accountable for defects. In turn, a lower expected investment induces the buyer to increase specification because of substitutability.

If investment and specification are complements, $q_{es} > 0$ and, as a result, the numerator is positive. If $\tilde{h} = h$ but $\alpha < 1$, then $k'(s^F) = \alpha q_s(s^F, e^F)h$ and $g'(e^F) = q_e(s^F, e^F)h$, which implies that both specification and investment will be below first-best. If $\tilde{h} = h$ and $\alpha = 1$, then both specification and investment will be at first-best level.

If $\tilde{h} < h$, $s^F > s^N$. Intuitively, the seller is expected to make some investment, i.e., $e^F > e^N = 0$, and this increases the gain from increasing good specification: $q_s(s, e) > q_s(s, 0)$ for all $e > 0$.

Formal authority mitigates the under-investment problem and under-specification problem as compared to the case in which courts take into consideration the allocation of real authority if the complementarity effect is sufficiently small. Note that if the strategic effect dominates the complementarity effect $\frac{\partial e^R}{\partial s} < 0$. Therefore, $k'(s^R) < \alpha q_s(s^R, e^R)h$, whereas $k'(s^F) = \alpha \left(q_s(s^F, e^F)h - q_e(s^F, e^F)(h - \tilde{h}) \frac{q_{es}(s^F, e^F)}{q_{ee}(s^F, e^F)\tilde{h} - g''(e^F)} \right)$, assuming that both s^R and s^F are positive. Because $k'(\cdot)$ is an increasing function, $s^F > s^R$ for the same or a greater level of e. At the same time, if $s^F > s^R$, it always holds that $e^F > e^R$ because of complementarity and the fact that in a regime of real authority the seller may not be held liable for a design failure. If complementarity is strong enough so that $\frac{\partial e^R}{\partial s} > 0$, the comparison between the two regimes becomes more ambiguous.

□

Appendix B

Alternative Modeling Approach

In what follows, I assume that it is always profitable to produce the good, even though it is going to be defective with probability 1, i.e., $\bar{v} - h \geq 0$.

First-best

I start by characterizing first-best investment and specification levels. Welfare is given by:

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

The first-best choice of e, given the specification level s, is:

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

$$g_e(e^*(s),s) = q'(e^*(s))h \tag{B1}$$

First-best specification of the good is:

$$s^* \equiv \arg\max_{s\geq 0}\ V(s) - [1-q(e^*(s))]h - k(s) - g(e^*(s),s)$$

$$v'(s^*) - k'(s^*) - g_s(e^*,s^*) + \underbrace{[q'(e^*(s))h - g_e(e^*(s),s^*)]}_{=0}\frac{\partial e^*(s)}{\partial s} \leq 0$$

Hence,

$$k'(s^*) = \max\{v'(s^*) - g_s(e^*,s^*), 0\} \tag{B2}$$

At the margin, the optimal specification level trades off the gain associated with a richer specification of the good, i.e., a better match with the buyer's needs, with a larger cost imposed on the seller to guarantee that the design is adequate. If the negative repercussion on the seller's cost is too large, relative to the benefits of the seller's investment, the optimal specification of the good is $s = 0$. Henceforth, I assume that $s^* > 0$.

Non-verifiable Design Failure

Suppose first that the design failure is non-verifiable. Seller chooses e to maximize:

$$U_S^N(e) = -g(e,s)$$

Therefore, $e^N = 0$. The parties agree on the following price:

$$p^N(s) = (1-\alpha)[V(s) - h]$$

The buyer's utility is given by:

$$U_B^N(s) = \alpha[V(s) - h] - k(s)$$

Maximization with respect to s yields:

$$k'(s^N) = \alpha v'(s^N) \tag{B3}$$

For α sufficiently large, the buyer over-specifies the design of the good relative to first-best (proof similar to that of Lemma 2).

Verifiable Design Failure - Formal Authority

When choosing how much to invest, the seller will maximize the following expected utility:

$$U_S^F(e,s) = -[1-q(e)]\tilde{h} - g(e,s)$$

The seller's efficient choice of e given s solves:

$$g_e(e^F(s),s) = q'(e^F(s))\tilde{h}$$

At the contracting stage,

$$p^F(s) = (1-\alpha)[V(s) - [1-q(e^F(s))]h - g(e^F(s),s)] + [1-q(e^F(s))]\tilde{h} + g(e^F(s),s)$$

and the buyer's expected utility is:

$$U_B^F(s) = \alpha[V(s) - g(e^F(s),s) - [1-q(e^F(s))]h] - k(s)$$

The buyer's optimal specification of the good is:

$$k'(s^F) = \max\left\{\alpha\left(v'(s^F) - g_s(e^F,s^F) + \underbrace{[q'(e^F)h - g_e(e^F,s^F)]}_{>0}\underbrace{\frac{\partial e^F(s)}{\partial s}}_{<0}\right), 0\right\}$$

where:

$$\frac{\partial e^F(s)}{\partial s} = -\frac{-g_{es}(e^F,s)}{q''(e^F)\tilde{h} - g_{ee}(e^F,s)} < 0$$

and

$$q'(e^F)h - g_e(e^F,s^F) = q'(e^F)h - q'(e^F)\tilde{h}$$

Note that $e^F > e^N = 0$ and $s^F < s^N$, because the buyer is concerned about the negative repercussions of a richer specification on the seller's investment. If damages are fully compensatory, i.e. $\tilde{h} = h$, $k'(s^F) = \alpha(v'(s^F) - g_s(e^F,s^F))$. Therefore, the buyer's specification is below first-best only if $\alpha < 1$, and when this is the case, the seller invests more than in first-best.

Distortion in investment and specification can be simultaneously eliminated if $\alpha = 1$ and $\tilde{h} = h$.

Verifiable Design Failure - Real Authority

Consider now the case in which a design failure is verifiable and the court assigns liability according to real authority.

$$U_S^R(e,s) = -[1-q(e)][1-\phi(s)]\tilde{h} - g(e,s)$$

The seller's best response of e given s yields:

$$g_e(e^R(s), s) = q'(e^R(s))[1 - \phi(s)]\tilde{h} \tag{B4}$$

In stage 1 they agree on the following price:

$$\begin{aligned} p^R(s) =&(1-\alpha)[V(s) - [1 - q(e^R(s))]h - g(e^R(s), s)] \\ &+[1 - q(e^R(s))][1 - \phi(s)]\tilde{h} + g(e^R(s), s) \end{aligned}$$

Therefore, the buyer's utility is:[49]

$$U_B^E(s) = \alpha[V(s) - (1 - q(e^R(s)))h - g(e^R(s), s)] - k(s)$$

The optimal choice of s satisfies:

$$k'(s^R) = \max\left\{\alpha\left(v'(s^R) - g_s(e^R, s^R) + \underbrace{[q'(e^R)h - g_e(e^R, s^R)]}_{>0}\underbrace{\frac{\partial e^R}{\partial s}}_{<0}\right), 0\right\} \tag{B5}$$

To see why, consider that

$$q'(e^R)h - g_e(e^R, s^R) = q'(e^R)h - q'(e^R)[1 - \phi(s^R)]\tilde{h} > 0$$

and

$$\frac{\partial e^R(s)}{\partial s} = -\frac{-\phi'(s)q'(e^R)\tilde{h} - g_{es}(e^R, s)}{q''(e^R)[1 - \phi(s)]\tilde{h} - g_{ee}(e^R, s)}$$

The denominator is always negative and, as a result, the sign of the derivative coincides with the sign of the numerator:

$$-\underbrace{\phi'(s)q'(e^R)\tilde{h}}_{>0} - \underbrace{g_{es}(e^R, s)}_{>0}$$

this is always negative.

When design failure is verifiable and the courts assign liability according to real-authority, the buyer specifies less and the seller invest more than when the design failure is not verifiable, i.e. $s^R < s^N$ and $e^R > e^N = 0$. In the real-authority regime, the seller always makes some investment as long as $\tilde{h} > 0$ and $\phi(s) < 1$. For any level of α the buyer specifies less the design of the good, because this increases the cost of the seller's investment and also has a negative impact on the seller's incentives to invest by reducing the probability that he is accountable for defects. Namely, because $\frac{\partial e^R(s)}{\partial s} < 0$.

Compared to formal authority, the buyer has a strategic incentive to under-specify the design of the good, that of increasing the likelihood that the seller is liable for a

[49] I assume the buyer's utility function to be strictly concave in s.

defective design. Notably, this incentive does not disappear when $\tilde{h} = h$. Therefore, under real-authority, it cannot be that both buyer's specification and seller's cooperative investment are first-best. To see this, suppose first that $e^R \geq e^*$, then $g_s(e^R, s) \geq g_s(e^*, s)$ for all s. Since $\frac{\partial e^R(s)}{\partial s}$ is negative, even for $\alpha = 1$, it holds that $s^R < s^*$. If $e^R < e^*$, then $g_s(e^R, s) < g_s(e^*, s)$ for all s. If so, s^R may be greater or smaller than s^*.

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