

Incomplete Contracts with Asymmetric Information: Exclusive vs. Optional Remedies

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1. Introduction

Law and economics scholars have always had a strong interest in contract remedies. Perhaps the most explored issue in contract law has been the desirability of various contract remedies, such as expectation damages, specific performance, or liquidated damages, to name the most common. Scholars have been debating for years, from various perspectives, the comparative advantage of these remedies.¹ Yet, most scholars have assumed that each of these remedies is *exclusive*. Interestingly, an analysis that assumes these remedies are *optional* (or *cumulative*) has not yet been explored, in spite of the fact that contract law provides the non-breaching party with a variety of optional remedies to choose from in case of a breach,² and in spite of the fact that parties themselves write contracts which provide such an option.³

In this paper we attempt to start filling this gap by studying the *relationship* between these remedies. Specifically, we study the conditions at which a contract that grants the non-breaching party an option to choose from optional remedies is superior to an exclusive remedy contract. We show that with two-sided uncertainty and asymmetric information between a seller and a buyer the interaction of the parties' distributions determines whether a contract shall provide for exclusive or optional remedies. Specifically, in the case of seller-breach, if the buyer's conditional expected valuation is larger than the seller's conditional expected valuation (in both cases- conditional that their expected valuations are above the buyer's mean valuation), then a contract which provides the buyer an option to choose between liquidated damages or specific performance (or actual damages) is superior.

Our analysis in this paper informs transactional lawyers of the relevant economic factors they should consider when deciding the optimal composition of remedies in a given context. Moreover, our analysis is relevant for courts that interpret contracts because it will help them to better understand whether rational parties would have agreed

¹ See for example, Tom Ulen, 1984.; Charles Goetz & Robert Scott., 1977.

² Chapter 7, Article 2 of the UCC provides a list of optional remedies, but parties can agree on any other remedy, provided they conform with some basic principles of contract law. See generally Article 1-102(3) to the UCC; and more particularly see Article 2-719(1). The entire of chapter 66 in Corbin is dedicated to "election of remedies".

³ It is suffice to recall the following prevalent contract clause: "Upon breach, the seller can choose, *at his discretion*....".

that a particular remedy be an exclusive remedy or an optional remedy when the language of the contract is ambiguous. Lastly, our analysis provides yet another economic rationale for why courts should enforce parties' liquidated damages clauses even if it seems ex-post over, or under, compensatory.

We present a model which shows when parties will agree on a non-exclusive liquidated damages clause. Under such a contract the parties stipulate ex-ante that the buyer will have the option to choose upon breach whether she prefers an optional remedy, such as actual damages or specific performance, to the pre-determined liquidated damages.

We focus on the ex-ante design of the contract in light of the new information that the parties anticipate they will gain after they draft the contract. Therefore, we assume that no renegotiation or investments are involved.⁴ We demonstrate the optimal way to design contract clauses which takes advantage of the information that the parties receive between the time they enter the contract and the time of actual breach. We further suggest that parties indeed use such clauses and that courts honor them.

After laying out the basic model we provide some extensions to it. As is well known, an exclusive liquidated damages contract is equivalent to granting the seller a call option to breach and pay, where the exercise price is equal to the amount of the agreed liquidated damages. What is perhaps less known is that a non-exclusive, or optional, contract, where the buyer can choose performance, is equivalent to giving the buyer a consecutive call option with the same exercise price. Yet, the consecutive call option to the buyer does not have to have the same exercise price but can rather have a different one. We call this new contract a two-price contract and show that it is even more efficient than the basic contract we have explored before. Next, we introduce more rounds of sequential options and show that an n-round contract approaches the first best, as n goes to infinity. We show numerically that within just 4 rounds, 96% of the allocative efficiency can be achieved.

Section two describes the legal background against which we have designed our model. Section three surveys the literature that evaluates contract remedies from an economic perspective. Section four presents a simple model with two-sided incomplete

⁴ Indeed, in an environment of asymmetric information renegotiation costs are high. More on this below.

information and with a liquidated damages clause. In section four we compare the performance of an optional remedy with an exclusive remedy and then determine the conditions of which regime should be applied. Section five discusses some interesting extensions meant to approach the first-best allocative efficiency. The appendix provides some details of the damage clause and collects the proofs.

2. The Law of Exclusiveness of Remedies

While the typical default remedy for breach of contract is expectation damages, other remedies may also be available. For example, where the goods are unique and damages are otherwise inadequate, the default remedy may be specific performance if enforcement does not impose too large of a burden on the court, and other conditions are met.⁵

Parties can enhance or restrict the set of available remedies in case of a breach. They can agree, for example, on liquidated damages; (see section 356 of the Restatement (Second) of Contracts and Article 2-718 to the UCC.) If the liquidated clause meets some necessary conditions, like not being a penalty or otherwise unconscionable, then courts may well enforce such clauses.

Parties can then further agree that the liquidated damages clause will or will not be the exclusive remedy. They can agree for example that the non-breaching party will be allowed, upon breach, to elect between receiving the pre-determined liquidated damages, or seeking specific performance. Courts will sometimes indeed honor such clauses.⁶ In a similar manner, parties can agree to allow the non-breaching party to elect between receiving the liquidated damages and recovering the ex-post actual damages. Historically, courts did not honor such clauses and determined that such an option in itself renders the liquidated damages clause an unenforceable penalty.⁷ Yet, recently it seems that court

⁵ See article 2-716 to the UCC and Restatement (Second) of Contracts articles 359 and 366.

⁶ See for example *Underwood v. Sterner*, 387 P.2d 366 (S.C Wash, 1963). For a more recent case see *Sweatt v. Intenrational Development Corp.*, 531 S.E.2d 192 (Ga. COA, 2000).

⁷ For example, in *Dalston Const. Corp. v. Wallace* 214 N.Y.S.2d 191 (N.Y.Dist.Ct., 1960) the plaintiff was explicitly allowed in the contract to seek actual damages if they came out to be higher than his liquidated damages. Refusing actual damages the court said “[t]he [liquidated] clause here does not disclose a fixed amount. In essence it fixes a minimum which must be paid by the [defendant] to the [plaintiff], but leaves the door wide open to [the plaintiff] to prove actual damage in addition to the so-called liquidated damage. This is no

may be more likely than ever before to honor such clauses.⁸ Alternatively, parties can agree that the liquidated damages be the exclusive remedy, and courts will honor it. For example, in a recent 2002 case the Appellate Court of Illinois refused to grant the purchaser of a townhouse specific performance (which is considered traditionally the default remedy for breach of land contracts) only because the contract explicitly provided that the purchaser's liquidated damages are his "sole remedy".⁹

A study of various standard industry contracts reveals that both types of contracts — where parties contract for exclusive or for optional liquidated damages — widely exist. For example, most standard real estate contracts state explicitly that in the event of breach, the seller's sole remedy is liquidated damages in the form of earnest money.¹⁰ In production contracts under which goods are specially manufactured for the buyer and are not readily resalable on the market, the buyer's exclusive remedy is liquidated damages.¹¹ The same holds in some service contracts wherein the amount of damages in the event of breach is not readily ascertainable.¹² Contracts for the sale of burglar or fire alarm systems are similar in that manner.¹³ On the other hand, in a standard contract of schools' invitation to bid for software, the liquidated damages are explicitly non-exclusive¹⁴, so is

settlement at all and it permits the [plaintiff] to have his cake and eat it too." A more recent case which applies a similar approach is *Jefferson Randolph Corp. v. Progressive Data Systems, Inc.*, 553 S.E.2d 304 (Ga. App., 2001). And see Farnsworth, *On Contracts*, (3rd ed, 2004) 320, and cases cited in his footnote 6.

⁸ For example in *Leahy Realty Corp. v. American Snack Foods Corp.*, 625 N.E. 2d 956 (Ill. App. 1993) the court allowed the non-breaching party to recover actual damages despite the existence of a liquidated damages clause after it found that the contract explicitly allowed that. And see *Noble v. Ogborn*, 717 P.2d 285 (Wash. App, 1986) (same) and *Northwest Airlines, Inc. v. Flight Trails*, 3 F.3d 292, 294-95 (8th Cir. 1993) (same). And see Farnsworth *id* for more cases.

⁹ *O'shield v. Lakeside Bank*, 781 N.E.2d 1114 (Ill.App., 2002).

¹⁰ See, e.g., *Mississippi Real Estate Contracts and Closings*, *Contracts for the Purchase of Real Estate* § 6:18. 10 *Ariz. Legal Forms, Bus. Org. LLC & Part.* § 27.4 (2d ed.). But sometimes they leave it open: 15C *Am. Jur. Legal Forms 2d Real Estate Sales* § 219:596.

¹¹ See, e.g., *West Pennsylvania Forms, Buyer's Right on Improper Delivery* § 2601. 4A *Vernon's Okla. Forms 2d, Com. & Consumer Forms* § 2-601--Form 2, 5 *Ariz. Legal Forms, Comm. Transactions* § 2.392 (2d ed.).

¹² For example, one form contract recommends the following language: "It is agreed by and between the parties that the Contractor is not an insurer, that the payments hereinbefore named are based solely on the value of the service in the maintenance of the system described, that it is impracticable and extremely difficult to fix the actual damages, if any, which may proximately result from a failure on the part of the contractor to perform such service and in case of failure to perform such service and a resulting loss its liability hereunder shall be limited to and fixed at the sum of fifty dollars as liquidated damages, and not as a penalty, and this liability shall be exclusive." 27 *West's Legal Forms, Specialized Forms* § 3.9 (3d ed.).

¹³ 27 *West's Legal Forms, Specialized Forms* § 3.9 (3d ed.), 6 *N.J. Forms Legal & Bus* § 11A:14, 6A *Texas Forms Legal & Bus.* § 11C:68.

¹⁴ 30 *West's Legal Forms, Specialized Forms* § 31.46 (3d ed.), 15A *Am. Jur. Legal Forms 2d Public Works and Contracts* § 216:25.

the liquidated damages clause in a standard “Tree Estimate Timber Sale Contract”¹⁵. Other types of standard contracts where liquidated damages are not exclusive are contracts for purchase business¹⁶, and agreements to transfer materials and intellectual property.¹⁷

Yet, exactly when parties would contract for exclusive liquidated damages clauses and when for optional ones is not clear. Below we present a model which attempts to shed some light on this question.

Much more litigation arises though in liquidated damages contracts which do not explicitly mention whether the liquidated damages are exclusive or optional, (we call it here “silent” contracts). Can the non-breaching party still seek specific performance or actual damages?¹⁸ In “silent” contracts the general default rule has two parts.¹⁹ First, the non-breaching party is *not* entitled upon breach to seek higher actual damages.²⁰ Second, and conversely, the non-breaching party *is* still entitled to seek specific performance, assuming the conditions for granting specific performance hold, (Restatement (Second)

¹⁵ 5E Nichols Cyc. Legal Forms s 5.6682.

¹⁶ 8 Nichols Cyc. Legal Forms s 8.1331.

¹⁷ Forms Legal & Bus. s 42:26.

¹⁸ We ignore the symmetric question of whether the *breaching party* can ask ex-post to pay lower actual damages instead of the higher liquidated damages. To do that, the breaching party may try one of three strategies. First, he may ask the court to strike down the liquidated damages clause for being a “penalty”. This has occasionally proved to be a successful strategy. Second, he may ask the court to strike down the liquidated damages clause because the actual damages are capable of accurate estimation. Third, he may argue that the liquidated damages are not the *exclusive* remedy and that the breaching party should be allowed to pay the actual damages. This has usually proved to be an unsuccessful strategy.

¹⁹ Corbin (2nd ed, 1964) sections 1061, 1070 and 1213.

²⁰ The leading UCC case is *Ray Farmers Union Elevator Co. v. Weyrauch*, 238 N.W.2d 47 (N.D. 1975) (plaintiff could not recover his actual damages but was rather restricted to the lower amount of the liquidated damages, despite the fact the liquidated damages clause was not expressly exclusive.) For a more recent case see for example *Orkin Exterminating Company, Inc. v. DelGuidice*, 790 So. 2d 1158 (Fla. COA, 2001). Interestingly, courts did find their ways to let the non-breaching party receive sometimes higher actual damages instead of the lower stipulated damages. They have done it in three ways. First, they have done it by determining that the breach which occurred is different than the breach that liquidated damages covered (*Murphy v. United States Fidelity & Guaranty Co.*, 100 A.D. 93, 94, 91 N.Y.S. 582, 583 (1905)). Second, they have done it by determining that the circumstances cause an exclusive liquidated damages clause to “fail of its essential purpose” (under article 2-719(2) to the UCC). See *Latimer v. William Mueller & son, Inc.* 386 N.W. 2d 618 (Mich 1986). (Liquidated damages clause in a defected seeds contract fail its essential purpose and therefore plaintiff is entitled to receive actual damages). And see *Lutz Farms v. Asgrow Seed Co.*, 948 F.2d 638 (same). Third, they have done it by determining that the small liquidated damages clause is unconscionable. See for example *Bonhard v. Gindin*, 142 A. 52,(N.J.Err. & App. 1928)(“In the present action to limit the damages to the amount expressed in the agreement as liquidated damages would be unconscionable.”)

of Contracts §357 (1979) and article 2-716 of the UCC).²¹ For example, in a recent case between “sophisticated parties” a court ruled that a “silent” liquidated damages clause did not preclude the utility company (the buyer of coal delivery services) from seeking specific performance from the railroad company, but did preclude the utility’s election of actual cost of obtaining alternate fuel.²²

Exactly why courts allow the non-breaching party in a “silent” contract to seek specific performance but not damages is however not clear.²³

²¹ The Restatement (Second) of Contract §361 (1979) reads “Specific performance or an injunction may be granted to enforce a duty even though there is a provision for liquidated damages for breach of that duty.” This might strike the attentive reader as weird because one of the pre-conditions for granting specific performance is that damages are inadequate. But if parties agreed on liquidated damages ex-ante, how can they be inadequate ex-post? Yet, courts have ruled that the mere existence of liquidated damages does not render damages adequate, and specific performance can still be granted. See for example *Carolina Cotton Growers Association v. Arnette* (D.C.S.C.1974), 371 F.Supp. 65 and *Washington Cranberry Growers’ Ass’n v. Moore*, 117 Wash. 430 (1921), where the court essentially granted specific performance against a cranberry farmer despite a liquidated damages clause. And See Corbin (2nd ed, 1964) section 1213 and Farnsworth On Contract, Vol 3, (3rd ed, 2004) at 173.

²² The language of the liquidated damages clause provided that the railroad company “shall” pay to the utility liquidated damages in case of a breach. The court, citing another case, said that “A ‘shall’ provision for liquidated damages gives the party who does not breach the contract only one option: he can sue for specific performance, but he cannot sue for actual damages; the stipulated figure is the only option he has for damages.” *Entergy Services, Inc. v. Union Pacific Railroad Co.* (Neb. 1999) 35 F. Supp. 2d 746, 754 and cases cited there. And see *Carolina Cotton Growers Association v. Arnette* where the defendant failed to deliver cotton as promised in the contract. The court allowed the plaintiff to specifically enforce the promise to deliver the cotton which the defendant had grown for him, despite the presence of a liquidated damages clause. 371 F. Supp. 65 (D.S.C. 1974). And see similarly *Manchester Dairy System v. Hayward*. 132 A. 12 (SC. N.H 1926) where the court ordered Hayward to deliver milk to the plaintiff (a cooperative) despite the existence of liquidated damages clause. A common problem with specific performance is the burden it imposes on the court in monitoring the performance. Yet, the latter problem is not as difficult as it may first seem because courts have indirectly enforced performance by granting a negative decree instead of a positive one, i.e. an injunction *not* to do something rather than monitoring a specific performance. For example, courts have historically enforced covenants not to compete by granting an injunction which prevents a former employee or a partner from working in the same area as her former employer. See *Wirth & Hamid Fair Booking v. Wirth*, 192 N.E. 297 (N.Y C.O.A, 1934). For more modern cases see for example, *Phoenix Orthopedic Surgeons v. Peairs*, 790. P.2d 752 (Ariz. 1989), *Brian McDonagh S.C v. Moss*, 565 N.E. 2d 159 (Ill. 1990), *Bradley v. Health Coalition, Inc.* 687 So. 2d 329 (Fla. 1999). Similarly, courts have granted injunctions preventing farmers from selling their harvest to anyone else but the plaintiff, indirectly enforcing the original contract. See for example, *Manchester Dairy System v. Hayward*. 132 A. 12 (SC. N.H 1926) (“While it is practically impossible to compel specific performance of a contract of this nature, there is abundant authority that the court may, by enjoining the contractor from selling his wares to any one else, place him in a position where his own interest may be powerful enough to induce him to perform his contract.”) and the cases cited in that case. And see Corbin (2nd ed, 1964) section 1206.

²³ Compare for example, *Ray Farmers Union Elevator Co. v. Weyrauch*, where the defendant breached the contract and failed to deliver wheat and durum to the plaintiff and the court held that the plaintiff could not recover his actual damages but is rather restricted to the lower amount of the liquidated damages, despite the fact the liquidated damages clause was not expressly made exclusive. 238 N.W.2d 47 (N.D. 1975) with *Manchester Dairy System v. Hayward*. 132 A. 12 (N.H.S.C 1926) where the court ordered Hayward to deliver milk to the plaintiff (a cooperative) despite the existence of liquidated damages clause.

Other times, courts interpret a “silent” liquidated damages clause as an exclusive remedy. Courts have done this by interpreting the contract as an “option contract” or “alternate performance contract” that allows the breaching party to pay liquidated damages and nullify the contract, thus preventing the non-breaching party from seeking specific performance.²⁴ What exactly distinguishes these contracts from a “silent” contract with liquidated damages which is found to be non-exclusive is unclear.²⁵

To sum up, the legal analysis has revealed that first, parties explicitly contract for both exclusive and optional liquidated damages clauses, yet it is not clear when they would prefer each type of clause. Second, that courts not always allow the non-breaching party to recover actual damages, even if the option was explicitly contracted for. Third, when the liquidated damages clause is silent, courts nevertheless usually allow the non-breaching party to seek specific performance, yet sometimes they do not, without any apparent reason for what account for the difference in their interpretation of the contract. Fourth, courts never allow the non-breaching party to seek actual damages in such circumstances.

These discrepancies demonstrate the need for a model that shows exactly when parties would contract for exclusive liquidated damages and when, in contrast, they would allow the non-breaching party to seek specific performance or damages. Such a model will be useful for courts when they interpret “silent” contracts as well as for lawyers to avoid “silent” contracts and be explicit about whether or not the liquidated damages clause is exclusive. Section 4 presents this model.

²⁴ Courts have done this even where the contract was not phrased as an option contract, and even if the asset was land. See for example, *Davis v. Isenstein*, 100 N.E. 940 (SC of Illinois, 1913); *Bank v. Lester*, 404 So. 2d 141 (Fla. App. 1981). See Farnsworth *id* at p 181.

²⁵ “To distinguish between liquidated damages and alternate performances requires angels to dance upon the heads of pins.” Debora Threedy, *Liquidated and Limited Damages and The Revision of Article 2: An Opportunity to Rethink The U.C.C.’s treatment of Agreed Remedies*, 27 Idaho L. Rev. 427,441. And consider: “Because of its ambiguity, the alternative performances device has been a method frequently used by courts to enforce clauses that they believed they could not enforce as liquidation of damages provisions.” Justin Sweet, *Liquidated Damages in California*, 60 Calif. Law Rev. 84, 94. And see Corbin *id* section 1213. “The fact that the contract provides that, in case of breach, the damage shall be as there admitted, does not of itself conclusively establish that the parties contemplated that, upon the breach thereof, damages would be an adequate remedy. It is a question of intention in each case, to be deduced from the whole instrument and the circumstances, and, if it appears that the performance of the covenant was intended, and not merely the payment of damages in case of breach, the contract will be enforced”, *Washington Cranberry Growers' Association v. Moore* (1921) 201 P. 773, at 777.

3. Related Literature

In this section we survey previous related work and distinguish our work. There are two groups of relevant literatures: One is economics of incomplete contracts and bilateral trading. The other is legal literature on property/liability rules. Current economics literature indicates that complex contracts that apply mechanism design approach can achieve first best when parties write the contracts at ex-ante stage. Moreover, simple contracts may achieve first best as well, but only if parties' realized valuations are observable and costless renegotiation is possible. In contrast, we explore a simple contract where the parties' realized valuations are assumed to be *unobservable*, which means that ex post renegotiation is costly; indeed we assume that it is prohibitively costly.²⁶ We nevertheless are able to approach first best. We now describe the literature in more detail.

Most of the literature applies mechanism design approach to optimal contracting, and they attempt to find ways to provide parties with incentives to truthfully reveal their valuations. Myerson & Satterthwaite (1983) showed in their seminal paper that with asymmetric information first-best is impossible to achieve, assuming that both the incentive-compatibility and individual-rationality constraints hold. (See also Diamond & Maskin (1979) and Stole (1992)). Because the parties own private information prior to contracting, the terms proposed reveal their private information to the other party. This

²⁶ A quick note on the renegotiation assumption is nevertheless necessary here. First, most papers that used non-contingent contracts needed the assumption of costless renegotiation to achieve first-best. Yet, a renegotiation game is never costless ex-post and hard to design ex-ante. It is thus questionable whether writing a non-contingent contract and designing a renegotiation game (which itself should be renegotiation proof) is indeed simpler than writing a contingent contract (Schmitz (2001)). Second, and more importantly, one should bear in mind that our information structure is less restrictive than many other papers because the decision whether to deliver or breach is made under asymmetric information, meaning parties' valuations are *not* observable. Indeed, renegotiation under such condition is by no means a costless process. Models which account for renegotiation typically assume that parties' valuations at the trade-or-renegotiate stage are observable. (Hart & Moore (1988), Chung (1991), Noldeke & Schmidt (1995), Spier & Whinston 1995, Edlin & Reichelstein (1996)). Third, some argue that parties may find ways to prevent renegotiation, or at least find ways to raise its costs significantly. Maskin and Tirole (1999) analyze several ways parties can commit to not renegotiate. Hart & Moore (1999) provide interesting responses. Fourth, even if renegotiation is simple, this paper provides a bench mark for assessing the change due to renegotiation (see Rogerson (1992)). Lastly, as Hart & Moore (1999) recently noted, both cases where parties can and cannot commit to not renegotiate- are worthy of study. As Hart and Moore argue, the degree of the parties' ability to committing not to renegotiate "is something about which reasonable people can disagree."

signaling can lead to distortions in the bargaining which undermine the efficiency. To overcome the impossibility of Myerson & Satterthwaite (1983), scholars (D'Aspremont & Gerard-Varet, 1979; Konakayama, Mitsui & Watanabe, 1986; and Rogerson, 1992) have studied mechanisms that are formed at the ex-ante stage, before parties learned their own valuations, i.e., when they are symmetrically (un)informed. In general, depending on the particular information structure they applied, first-best was shown to be achievable through contingent ex-ante contracts. However, since most real-life contracts are simple rather than contingent contracts (which require the parties to report their realized valuations at the interim stage), a question arises: whether simple ex-ante contracts can induce efficient trading. Chung (1991), Aghion, Dewatripont and Rey (1994) and Noldeke and Schmidt (1995), among others, proved that in some environments a simple ex ante contract plus a renegotiation design can replace a complex contingent contract to achieve efficient outcomes. This holds true under the assumption that the realized valuations are observable to both parties at the interim stage, so that with the ex ante agreed renegotiation plan efficient trading is achieved.

We also focus on simple fixed-term contracts but our work is different in that we assume that a party's valuation after she has learned it, is *not* observable to the other party. Instead, parties at the ex-ante stage anticipate that at the trade-or-breach stage, they will face asymmetric information and therefore consider the other's valuation as a random variable. We explore whether a simple contract can still mimic a contingent one to achieve efficiency when the information is asymmetric at the interim stage and renegotiation is prohibitively costly. We demonstrate in Section 5 that a simple fixed-term sequential-option contract indeed can approach first best under two-sided uncertainty and asymmetric information.

Our work is different from the contingent ex ante contract literature in that we focus on simple contracts instead of contingent mechanisms. Contingent contracts have been criticized for lack of simplicity of design, ease of enforcement and robustness to renegotiation (Tirole, 1986; Rogerson 1992; Harmelin & Katz, 1993). They are also susceptible to courts' errors (Zhang & Zhu, 2000). We, therefore, restrict our attention to non-contingent contracts, which are more commonly used in practice and are easier to enforce. The good efficiency properties of simple contracts in our model contribute to

explaining why simple fixed-term contracts are dominant in practice. Traditionally, economists have two explanations: First, there are high transaction costs of writing and enforcing complex contingent contracts. Second, through ex post renegotiation simple contracts can achieve the efficient outcome. We showed that even when ex post renegotiation is not available, simple contracts are still quite efficient through the exercise of sequential options.

Within the non-contingent contract literature, one can find fixed-price contracts, with or without damage clauses, e.g., Shavell (1980, 1984), Rogerson (1984), Aghion & Bolton (1989), Chung (1992), Spier & Whinston (1995), Edlin and Reichestein (1996), Miceli (1997), Zhu (2000), Zhang & Zhu (2000). These papers usually deal with one-sided uncertainty with or without accounting for possible renegotiation, and the realized valuations are observable at the interim stage. Some of these articles, following Shavell (1980, 1984) and Rogerson (1984), compared several commonly used damage measures and the incentives they provide for parties to breach and rely. Edlin (1998) and Edlin & Schwartz (2003) are excellent surveys. Our paper is different from these articles in that the information is not observable but asymmetric at the interim stage²⁷, and the parties face two-sided uncertainties.

Our paper is closely related to the legal literature on property/liability rules, especially relevant are a series of very interesting papers by Ayres and his coauthors (Ayres and Balkin, 1996; Ayres and Goldbart, 2001, 2003; Knysh, Goldbart, & Ayres, 2004) and a paper by Avraham (2004). These papers investigate an optional liability rule to induce efficient taking of entitlements under two-sided asymmetric information. With the distributions of valuations as common knowledge, the court as a welfare maximizer can design an optional liability rule in which each party in sequential order can take the entitlement with specific taking prices. They show that this optional liability rule can improve efficiency. Our paper is inspired from this literature, what we adds to this literature lies in several aspects. First, though they mentioned the potential application to contract remedies, they did not apply the idea to contract explicitly. We focus our analysis on contract remedies, and found the model is well matched with the (non)exclusiveness distinction of the damages clause in real-life contracts. Furthermore

²⁷ And therefore we assumed no renegotiation.

we derive the explicit conditions under which the parties shall apply non-exclusive damages, this is useful for transactional lawyers and courts to instruct drafting or interpret contracts. Second, and most importantly, with a model focusing on contract remedies specifically we show that even when the information is not observable after its realization (so that efficient ex post renegotiation is impossible), a simple fixed-term contract still can arbitrarily approach the efficient outcome. This greatly expands the efficiency of simple contracts in the incomplete contract literature²⁸, while the legal literature on property/liability rules did not reach this insight when discussing outside of contracting context. Third, in the legal literature on property/liability rules, it is a third party---the court---that decides on the liability rules. They don't discuss the parties' participation constraint by simply assuming that the parties are already in the game (dispute), the only task is for the court to decide the liabilities. In contrast, in our model it is the parties themselves coming together at ex ante stage to decide on remedies. By jointly choosing the remedy and committing to it at ex ante stage, a Pareto improvement over the regular contracts is achieved. In a sense, our remedy choice is endogenous, while the liability choice in the property/liability literature is exogenous for the parties.

4. The Model--- with Liquidated Damages

4.1 The Setting

At Time 1 a seller-supplier and a buyer-manufacturer (both are risk-neutral) enter a contract for the sale of a single unit of indivisible goods that the buyer-manufacturer needs for its production of finished goods. The seller receives the money upon performance, that is, when he supplies the good sometime in the future, call it Time 2. Among other things, the parties agree on a price and liquidated damages to be paid in case the seller does not deliver in Time 2. There is uncertainty about the seller's cost of production due to future fluctuations in the market prices for the inputs for the materials the seller promised to deliver. Thus it is assumed that seller's cost, c , is drawn from a

²⁸ As discussed before, the previous literature (e.g., Chung, 1991; Aghion and Dewatripont, 1994, and Noldeke and Schmidt, 1995) only demonstrated that with interim-observable information, a simple ex ante contract can achieve efficient outcome.

density function $f(c)$ with cumulative density function denoted $F(c)$ in the interval $[\underline{c}, \bar{c}]$. There is also uncertainty about buyer's valuation of the good due to future fluctuations in the market prices of the products the buyer ultimately manufactures and sells. Thus, it is assumed that buyer's valuation, v , is drawn from a density function $g(v)$ with cumulative density function denoted $G(v)$ in the interval $[\underline{v}, \bar{v}]$, where $G(\cdot)$ and $F(\cdot)$ are independent and common knowledge.²⁹ This two-side uncertainty at Time 1 is what makes the determination of liquidated damages difficult. What is clear, however, is that by the time the parties' dispute will be deliberated in courts, call it Time 3, both parties will have learned their own valuations. The following chart presents the timeline.

Chart 1- Time line for the model with liquidated damages.

1	2	3
Parties enter a contract	Parties learn new information	seller delivers or breaches
		Court decides and parties obey

At Time 1, the seller and the buyer are symmetrically uninformed about each other's as well as their own valuations. They enter a contract with a price, p , and liquidated damages clause, d . Without loss of generality, and for simplicity, we assume that the buyer has the entire bargaining power so the seller's surplus from the contract is assumed to be zero. This entails that the buyer makes a take-it-or-leave-it offer of both the price, p , and the amount of the liquidated damages, d .³⁰

We note that the price and liquidated damages written in the contract are correlated and reflect the legal regime employed by the courts that the parties are expected to face at Time 3, if the seller does not deliver at Time 2. Importantly, we allow the parties to decide in Time 1 about the mechanism by which the liquidated damages

²⁹ Our basic results apply to the case of correlated distributions as well.

³⁰ Our results remain the same for any allocation of bargaining power, $\theta \in [0,1]$, between the parties. This is so because we did not consider investments and parties contract at the ex ante stage.

will be paid upon breach. This will be called either a *Regular Legal Regime* (RLR) or an *Option to Enforce Regime* (OER). More on this below.

In the interim period between Time 1 and Time 2, both parties learn their true valuations but cannot make any changes to the contract between them (no renegotiation after Time 1). Possible justifications for the parties learning more about their true valuations only after Time 1 is that new information that was unknown before (but which was anticipated to be known later) is now revealed. For example, the seller learned his exact cost of performance after OPEC withdrew its threat to raise oil prices, or, the buyer learned that the product she intends to manufacture was approved by some federal agency for distribution in the US, and so forth.

At Time 2 the seller, after learning his exact cost of performance, decides whether to deliver the good or breach. In making his decision the seller takes into account the price and liquidated damages agreed upon in Time 1 and the legal regime parties are expected to face at Time 3, if the seller does not deliver. The buyer's valuation is not observable to the seller (or verifiable to third parties). Instead, the seller continues to consider the buyer's valuation as a random variable.

At Time 3 the court does *not* hear evidence about the damages that the breach of the promise to deliver caused but rather *always* enforces the agreement between the parties, including the legal regime parties agreed on. Specifically, at Time 3, there are two possible regimes that the court can apply. First, RLR, in which if the seller decides to breach he pays damages that are equal to the liquidated damages, d_R . We call it Regular Legal Regime, because this is the legal regime the literature considers for liquidated damages. Second, an OER legal regime, in which the buyer can insist on getting specific performance over receiving the liquidated damages, d_O .³¹ If the buyer chooses to get the liquidated damages, the seller can then pay the liquidated damages. Yet, if the buyer chooses specific performance, the seller must deliver. At Time 3, when the buyer makes

³¹ To keep this already long paper somewhat shorter we consider here only the option to enforce and do not consider buyer's option to recover actual damages. In a separate working paper we consider that regime as well.

her decisions, the seller's realized cost of performance is not observable to the buyer or verifiable to the court.³²

We now compare the incentives to breach and parties' expected payoffs under RLR versus under OER.

4.2 Analysis

4.2.1 Regular Legal Regime.

When the legal regime is RLR, (that is when the seller can choose in Time 3 whether to deliver or breach and pay the liquidated damages), the buyer offers the seller in Time 1 a take-it-or-leave-it contract (p_R, d_R) , where p_R is the price and d_R is the liquidated damages under RLR. Price is payable upon performance. The seller will get $p_R - c$ if she performs, and $(-d_R)$ if she breaches. Therefore, she will breach if $c > p_R + d_R$. We denote $k_R \equiv p_R + d_R$ where k_R is the breach threshold. The seller will therefore breach if $c > k_R$. If the contract is accepted by the seller, the buyer will get an expected payoff which is equal to:

$$\pi_R^B = F(k_R)[E(v) - p_R] + [1 - F(k_R)]d_R$$

The first term on the right-hand-side represents the buyer's expected payoff when the seller decides to perform, and the second term represents the expected payoff when the seller decides to breach.

The seller's expected payoff (if she accepts the contract) is:

$$\pi_R^S = F(k_R)[p_R - E(c/c \leq k_R)] + [1 - F(k_R)](-d_R)$$

The first term represents the seller's expected payoff if he performs, and the second term represents his expected payoff if he breaches.

³² This is a major difference between our model and the models considered in the literature on incomplete contracts. Like other models in the literature we assume that parties in Time 1 only observe each other's distributions. In addition to that we also assume that parties do not know their own valuation, but rather have only an estimate of it. Parties in this sense are symmetrically uninformed: they both observe nothing but their own and each other's distributions. No private information exists. In Time 2 asymmetry of information is introduced. Parties learned their own valuation but still cannot observe (and definitely not verify) their opponent's valuation, but only its initial distribution.

By assumption, the buyer has the entire bargaining power and therefore can extract the entire ex-ante surplus, which means that the participation constraint is binding. Note however that *ex-post* the seller might get some positive payoff because he possesses private information about his- by then realized- production cost.

The buyer will choose k_R to maximize the joint payoff and then manipulate the price to guarantee the seller a zero expected payoff,

$$\text{Max}_{k_R} \pi_R^B + \pi_R^S = F(k_R)E(v) - \int_c^{k_R} c dF(c).$$

The equilibrium is summarized in Lemma 1:

Lemma 1 *Under RLR with Liquidated Damages, the equilibrium is:*

$$d_R^* = \pi_R^{B^*} = \int_c^{E(v)} F(c) dc,$$

$$p_R^* = E(v) - d_R^* = E(v) - \int_c^{E(v)} F(c) dc,$$

$$\pi_R^{S^*} = 0.$$

Remark. It is a standard result that expectation damages (under RLR) induce an optimal level of breach with one-sided uncertainty, eg. Miceli (1997, p 73). Observe that $d_R = E(v) - p_R$ means that the equilibrium liquidated damages equals the *expected* expectation damages. Thus, although from the *ex-ante* perspective the liquidated damages induce an optimal level of breach, the ex post breach might not be optimal. Specifically, in this case the seller breaches whenever $c \geq E(v)$. This is inefficient in cases in which $v > c > E(v)$. Conversely, the seller will deliver whenever $c < E(v)$, and this is inefficient in cases in which $v < c < E(v)$.

4.2.2 Option to Enforce Regime.

When the legal regime is OER, (that is when the buyer can insist, upon breach, on specific performance), the buyer offers the seller in Time 1 a take-it-or-leave-it contract (p_o, d_o) , where p_o is the price and d_o is the liquidated damages under OER. Price is

payable upon performance. As before, we denote the breach threshold $k_o \equiv p_o + d_o$. Obviously, the buyer will insist on delivery if $v \geq k_o$ and will agree to breach otherwise. If the seller performs he will receive $p_o - c$. The seller's expected payoff when he attempts to breach is $G(k_o)(-d_o) + [1 - G(k_o)](p_o - c)$. Hence, if $c \geq k_o$ the seller will prefer to breach; otherwise he will deliver.

If the seller accepts the contract, the buyer will get an expected payoff of:

$$\pi_o^B = F(k_o)[E(v) - p_o] + [1 - F(k_o)]\{G(k_o)d_o + [1 - G(k_o)][E(v/v \geq k_o) - p_o]\},$$

The first term on the right-hand-side represents the buyer's payoff if the seller performs. The second term represents the payoff if the seller attempts to breach. The first term in the curly parentheses is the payoff when the buyer agrees to the breach, and the second term is the payoff when she insists on specific performance. Similarly, the seller's expected payoff (if she accepts the contract) is:

$$\pi_o^S = F(k_o)[p_o - E(c/c \leq k_o)] + [1 - F(k_o)]\{G(k_o)(-d_o) + [1 - G(k_o)][p_o - E(c/c \geq k_o)]\}.$$

As before, the buyer can choose k_o to maximize the joint payoff and then manipulate the price to guarantee the seller a zero expected payoff,

$$\text{Max}_{k_o} \quad \pi_o^B + \pi_o^S = F(k_o)E(v) + [1 - F(k_o)] \int_{k_o}^{\bar{v}} v dG(v) + G(k_o) \int_{k_o}^{\bar{c}} c dF(c) - E(c). \quad (4.1)$$

Denote $h(x) \equiv \frac{f(x)}{1 - F(x)}$, $\kappa(x) \equiv \frac{g(x)}{G(x)}$, and $\lambda(x) \equiv \frac{h(x)}{h(x) + \kappa(x)}$.³³ We have the

following Lemma 2:

Lemma 2 *The joint expected equilibrium payoff is*

$$\pi_o^{B*} = F(k_o^*)[E(v) - E(c/c \leq k_o^*)] + [1 - F(k_o^*)][1 - G(k_o^*)][E(v/v \geq k_o^*) - E(c/c \geq k_o^*)],$$

where k_o^* is the solution to

$$k_o^* = \lambda(k_o^*)E(v/v \leq k_o^*) + [1 - \lambda(k_o^*)]E(c/c \geq k_o^*). \quad (4.2)$$

Proof: The first order condition of the buyer's maximization problem above is:

³³ $h(x)$ is the hazard rate of c , i.e., the probability of $c = x$ given that $c \geq x$. $\kappa(x)$ is the probability of $v = x$ given that $v \leq x$; $\lambda(x)$ measures the relative sizes of these two probabilities.

$$\left[\int_{\underline{v}}^{k_o} v dG(v) - k_o G(k_o) \right] f(k_o) + \left\{ \int_{k_o}^{\bar{c}} c dF(c) - k_o [1 - F(k_o)] \right\} g(k_o) = 0. \quad (4.3)$$

(4.2) follows from (4.3). QED.

Remark. When setting the breach threshold, the buyer faces a trade-off. Increasing k_o (holding p_o constant, but increasing d_o) will increase the damages she receives from the seller in the event of breach, yet the seller's probability of breach incentive is reduced as a result of the higher damages. Balancing this trade-off, the optimal breach threshold, k_o^* , is the weighted sum of the buyer's lower-than-threshold truncated expected value and the seller's higher-than-threshold truncated expected cost.

Uniform Distribution Example: If c is uniformly distributed on $[\underline{c}, \bar{c}]$, and v is uniformly distributed on $[\underline{v}, \bar{v}]$, then we derive from (3.2): $k_o^* = (\bar{c} + \underline{v})/2$. The optimal breach threshold is the midpoint of the buyer's lower-bound and the seller's upper-bound values. It is the midpoint of the specific intersection of the parties' distributions in which the uncertainty whether the buyer's valuation or the seller's cost is greater exists (in all other regions, the choice is easy). The following diagram represents it:

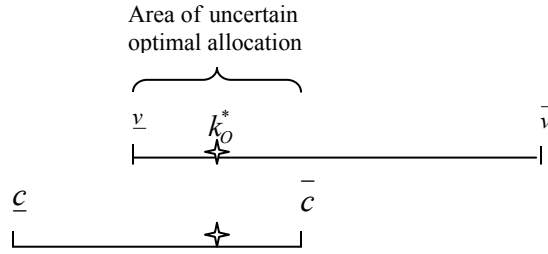


Figure 1. Optimal Breach Threshold with Uniform Distribution

Interestingly, under OER the breach threshold, k_o^* , can be larger or smaller than the breach threshold under RLR, which was $E(v)$. Lemma 3 determines the conditions at which the threshold under OER will be larger than the threshold under RLR.

Lemma 3

If $g(E(v))[1 - F(E(v))][E(c/c \geq E(v)) - E(v)] < f(E(v))G(E(v))[E(v) - E(v/v \leq E(v))]$,
then $k_o^* < E(v)$.

Proof: See the appendix.

Remark. (a) Lemma 3 suggests that the relative scale of two effects around the critical value $E(v)$, which was the optimal breach threshold under RLR, determines whether k_o^* is above or below $E(v)$. Suppose that under OER we still set the breach threshold at $E(v)$. Then one effect is in force when the buyer's value is $E(v)$, and the seller's cost of performance is above $E(v)$ (this happens with probability $g(E(v))[1 - F(E(v))]$). In this case, the seller wants to breach but the buyer is indifferent between breach and performance. Breach is efficient in this case, and the seller's expected cost savings from successful breach is the forgone expected cost minus the damages that he would have needed to pay, $E(v)$. The other effect occurs when the seller's cost is $E(v)$ and the buyer's value of performance is below $E(v)$ (this happens with probability $f(E(v))G(E(v))$). In this case, the buyer wants the seller to breach but the seller is indifferent between breach and performance. Breach is efficient in this case, and the buyer's expected gain from breach is the damages she would have received, $E(v)$, minus her expected value. If the first effect is dominated by the second effect, the buyer (contract designer) will have an incentive to lower the breach threshold from $E(v)$ to encourage the seller to breach.

(b) Notice that our result is different from Stole (1992). Stole showed that efficient stipulated damages are always under-compensatory (and thus the penalty doctrine is justified). Yet, in our model this result does not always hold. If the condition in Lemma 3 is not satisfied we might have over-compensatory damages (even without considering the strategic effect to the third parties, see Edlin and Schwartz (2003) for a concise summary of the literature). The difference between our result and Stole's is due to the different informational structure and the proposed OER where the liquidated damages clause is not exclusive; a regime that Stole does not consider.

The question that we are left with is whether RLR or OER yields a higher joint payoff.

Proposition 1 summarizes.

Proposition 1 *In an environment of two-sided uncertainty and private information, OER is Pareto superior to RLR, if*

$$E(v/v \geq E(v)) > E(c/c \geq E(v)) \text{ and } E(v/v \leq E(c)) > E(c/c \leq E(c)).$$

Proof: See the appendix.

Remarks. (a) If it is the seller that initiates breach, OER dominates RLR if the buyer's expected valuation is greater than the seller's expected cost, so long as both values are higher than $E(v)$. Recall from Lemma 1 that $E(v)$ is the optimal breach threshold under RLR. Indeed, under RLR whenever the seller's cost is higher than this threshold, he will breach the contract. The interesting question is whether it is then efficient to breach the contract. Proposition 1 states that OER Pareto dominates RLR whenever the buyer's mean-valuation above the RLR breach threshold is higher than the seller's mean-cost above that threshold. Indeed, in that case from the ex-ante perspective, performance is more likely to be efficient than breach. The buyer is likely to value the good at more than the seller's cost. Under these circumstances shifting from RLR to OER, and thus providing the buyer with the option to enforce, is efficiency-enhancing. The condition for the buyer-breach case is symmetric ($E(v/v \leq E(c)) > E(c/c \leq E(c))$).

(b) The condition in the proposition implies that the balance between two effects-- the mean effect and the variance effect—determines which legal regime is better.

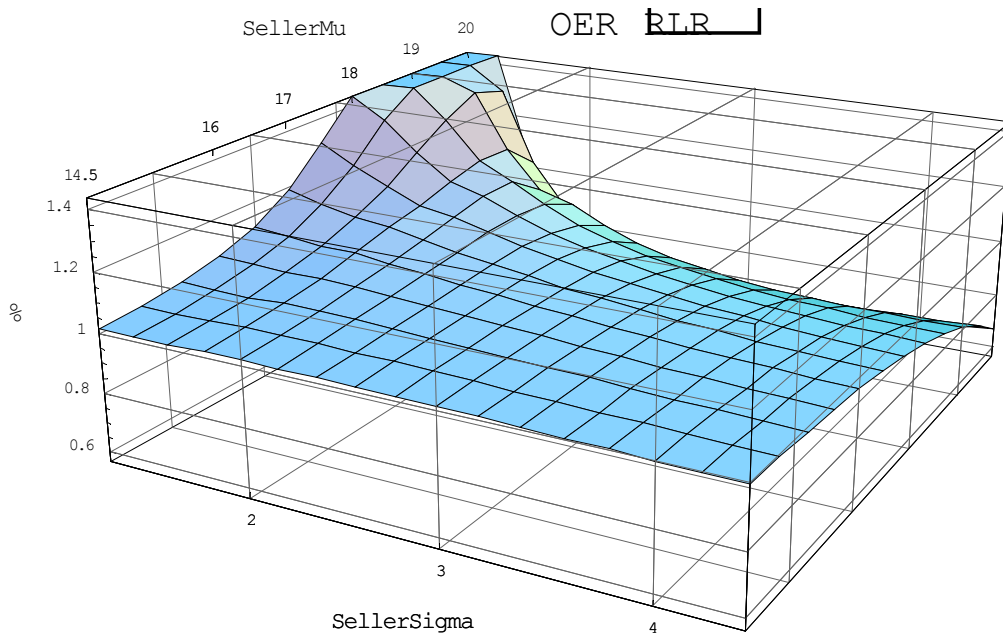
(c) Because neither of the legal regimes is unconditionally superior, courts should allow the parties to choose the type of legal regime they prefer. Specifically, the buyer should be allowed to offer the seller either an RLR-like contract, (p_R, d_R) , or an OER-like contract, (p_O, d_O) . The seller is indifferent as his expected payoff is always zero. But, for the buyer the choice of legal regime is important. As the buyer can observe both distributions in Time 1, she will prefer the (p_O, d_O) contract whenever the condition stated in Proposition 1 is met; otherwise she will prefer the (p_R, d_R) contract. The buyer's choice of contracts renders this regime to be *always* Pareto superior to the current RLR regime. Proposition 2 summarizes:

Proposition 2 *In a regime of double-sided uncertainty where specific performance and liquidated damages clauses are honored, allowing parties to choose the legal regime (RLR or OER) is Pareto superior to RLR and OER. .*

4.3 A Numerical Example

When parties distributions are normally distributed, analytically solving the model for the contracts p_O, d_O and p_R, d_R is difficult. We therefore solved it numerically. First, without loss of generality, we assumed that the buyer's valuations are normally distributed with a mean of 18.5 and a standard deviation of 2.5. Second, we assumed that the seller's costs are normally distributed with a relatively low mean and standard deviation. Without loss of generality, we assumed the seller's mean equals 14.5 and the standard deviation equals 1.2. Third, we calculated (p_O, d_O) ; (p_R, d_R) and the joint payoff for both the OER and RLR contracts. Then we plotted the *ratio* between the joint payoffs. Fourth, we increased the uncertainty about the seller's valuation (as represented by the standard deviation) by 0.2 and performed the above routine again. We continued performing these four steps until the standard deviation was equal 4.4. Observe at this point that we solved the model for a seller whose mean valuation is relatively low, while manipulating the uncertainty about his valuation (as represented by the standard deviation) from a standard deviation of 1.2 (which is much lower than the buyer's standard valuation) to a much larger standard deviation of 4.4.

The fifth and last step was to increase the seller's mean by 0.5 and do all the above steps again, until the mean reaches 20. Thus, in effect, we calculated the ratio of the joint payoffs under OER and RLR for all iterations between the buyer and the seller, where the latter's valuation was assumed to be normally distributed with a mean between 14.5 to 20 and standard variation between 1.2 to 4.4. Observe that we allow for the seller's mean to be higher than the Buyer's mean. Parties may nevertheless contract in such cases due to seller's option to breach. The next graph presents our results.



Graph 1- A Comparison of the Legal Regimes

The Z-axis in Graph 1 presents the ratio of the joint payoffs under OER and RLR. The middle of the Z-axis is the 1:1 point where both regimes yield the same joint payoff. The X-axis presents the seller's possible standard deviations (which runs from 1.2 to 4.4), whereas the Y axis presents his possible means (which runs from 14.5 to 20).

Graph 1 shows that when the seller's mean is relatively low, both regimes yield roughly the same joint payoff, despite the relative difference between their respective standard deviations. The intuition behind this result is that when the seller's costs are relatively low, he will always perform. Thus, neither the RLR, which allows him to breach and pay damages, or the OER which allows the buyer to insist on performance, are required to induce performance.

Graph 1 also shows a peak on the upper left side and a valley on the upper right side of the graph. Starting with the valley, Graph 1 shows that the larger the seller's means and standard deviations become, the more efficient RLR becomes relative to OER. The intuition is that when the parties' means become closer to each other and, in addition, there is a lot of uncertainty regarding the seller's ex-post cost of production. In those cases, a rule which only grants the seller the option to breach and pay damages will be more efficient. Indeed, this is exactly what RLR does.

Switching to the peak at the upper left side, Graph 1 shows that when the seller's mean is large yet his standard deviation is small, the better OER becomes relative to RLR. The intuition is that when parties' means are close to each other and there is not much uncertainty about the seller's ex-post cost of production, then there is a higher probability that the buyer's valuation will exceed the seller's cost. In those cases a rule that also grants the buyer an option to enforce will be more efficient. Indeed, this is exactly what OER does.

Lastly, observe that when the seller's mean is higher than the buyer's mean of 18.5, RLR becomes better even for low seller's sigma. The reason is that even with a low sigma the seller is more likely to have a higher valuation, and therefore letting him decide about the breach is superior.

Our numerical model enables us to take a closer look at the specific price and damage clauses that the parties will agree on. Consider first the different prices that OER and RLR contracts will have. A buyer's subsequent option to enforce makes the seller worse off under the same price and damage term because he loses the power to unilaterally breach. Thus, one would expect that the buyer will "compensate" the seller for the switch from an RLR contract to an OER contract, either by offering a higher price or by allowing the seller to pay lower damages in case of a breach, or any combination the two. Indeed, our numerical example confirms this intuition. The buyer will "bribe" the seller to switch from the RLR to OER contract, with either a higher price, lower damages, or both. Graphs 2a and 2b in the appendix present the results.

An interesting result of our research is that sometimes parties will agree on *negative* damages under the OER contract. As is shown in the appendix, when the seller's sigma is relatively small, the stipulated damages that the seller will have to pay in case of a contract breach are negative. That is, in these circumstances, when the seller attempts to breach the contract, the buyer might well agree to *pay* to the seller the predetermined stipulated amount in order to prevent the seller from performing.³⁴ We demonstrate this claim and explain its intuition in the appendix.

4.4 The Two-Price Contract

³⁴ Compare to Ayres and Madison (2000).

So far, to highlight the role of the option to enforce, we have assumed that in the OER contract, if the buyer insists on performance she could get performance and still pay the original price, p_o . We now relax this restriction in the Option to Enforce Regime. In this section we consider the possibility that the OER contract will stipulate two different prices for the two scenarios of performance (clearly seen from the game tree below, Figure 3)----one is the seller's voluntary performance in the first place; the other is the seller's involuntary performance, which is resulted from the buyer's insistence. We surely can differentiate these two scenarios in optimal contracting. Specifically, we add an additional variable, Δ , to the model, where Δ is an additional price the buyer needs to pay in the case she insists on performance. Thus, the buyer offers the following contract to the seller: $(p_o, p_o + \Delta, d_o)$. The game tree is as follows:

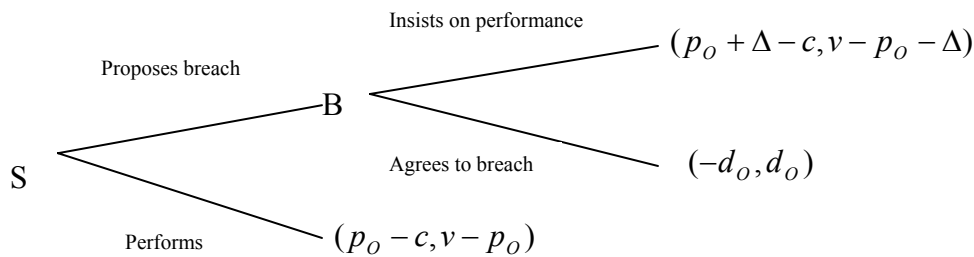


Figure 4. Option-to-Enforce game with two-price contract

Does a two-price contract yield a higher joint payoff than a Single-Price contract? Intuitively, a Two-Price contract should be superior to a Single-Price contract. A Single-Price contract is equivalent to a Two-Price contract where Δ is equal to zero. Thus, once the restriction that Δ is equal to zero is removed--- as is the case in a two-price contract--one would expect the joint payoff to increase. Put differently, the buyer who makes a take-it-or-leave-it offer knows that the seller might behave strategically (over-asking breach to get a higher payment in cases of buyer-insistence of performance) and can always choose a Δ equal to zero to prevent it. If she chooses a Δ larger than zero, it must yield her a higher expected payoff. Since the seller's expected payoff is equal to zero, a higher expected payoff for the buyer entails a higher joint expected payoff. In the appendix we prove this more formally.

Proposition 3 *With two-price contract, OER is always Pareto superior to RLR.*

Proof: in the Appendix.

Remark. (a) The two-price OER contract further partitions the information spaces of the parties. A single-price OER contract partitions the buyer's and the seller's information spaces using a single threshold value; in contrast, a two-price OER contract partitions the parties' information spaces using two separate optimal threshold values, and hence can further reduce the area of the inefficient regions.

(b) One may wonder whether parties can do even better by designing a more general n-round sequential options contract. For instance, one may consider granting the seller an option to insist on breach, but only if he pays higher damages, and then the buyer could insist on performance, but only if she pays a higher price, so on and so forth. As we show in Section 5 below such a contract can approach first best.

4.5 The Desirability of an Ex-Ante Contract.

In our model parties are not required to make investments prior to the seller's decision whether to breach and the buyer's decision whether to agree or insist on performance. One may wonder whether parties would be better off waiting until they learn their valuations and then sign a contract. Contracting at a later stage might be presumably more efficient, because more information is on the table.³⁵

The reason that parties bother writing a contract at the ex-ante stage when no investments are required is that at this stage they are symmetrically informed, or more accurately, symmetrically uninformed. In contrast, in the interim stage after they learn their own valuations they are *asymmetrically* informed. Designing a contract under information asymmetry is not an easy task due to the parties' strategic behavior. Indeed, the optimal contract designed in the interim stage is not necessarily more efficient than even a simple fixed-term contract designed in the ex-ante stage.³⁶ The benefits from the increase of

³⁵ We thank Omri Ben-Shahar for bringing this issue to our attention.

³⁶ *An example with uniform distribution:* If the buyer's valuation and the seller's cost are both uniformly distributed on $[0,1]$, the optimal interim trading mechanism (which is incentive compatible and individually rational)---Myerson and Satterthwaite mechanism (See Myerson and Satterthwaite, 1983, p.

information in the interim stage does not necessarily outweigh the disadvantages of the parties' strategic attempts to extract more rent. In the Appendix we show the conditions at which the ex-ante contract is superior to the interim contract.

5. Contracts under Higher-Order Sequential Option Remedy Regime

5.1 An n-Round Sequential Option Contract

The two-price OER contract resembles an ascending auction³⁷, by further partitioning the information space relative to the RLR contract. In the RLR contract, only the seller's information space is partitioned when he exercises his option to breach and pay damages. In the two-price OER contract, the seller signals his information through the breach decision in the first round, then the buyer in the second round signals her information through insistence or not on the performance. Therefore, the two-price OER contract reveals more information and can therefore lead to a more nuanced allocation. Following this logic, if we add more rounds of sequential options to the game, the parties' information spaces can be further partitioned to smaller sub-intervals, leading to a more efficient allocation. To following example demonstrates this claim for uniform distributions.

Assume that both the seller's cost and the buyer's valuation are uniformly distributed on the closed interval $[0,1]$. The basic game is the following: At Time 0, the parties sign a contract to trade some good (or service). At Time 1, the parties learn their

276-277; or, Chatterjee and Samuelson, 1983) ---is to transfer the good if $c \leq v - (1/4)$, otherwise, no trade takes place. The expected payoff of this mechanism is:

$$\pi_{MS}^{ex-ante} = \int_{1/4}^1 \int_0^{v-(1/4)} (v-c)dc dv = 9/64.$$

While our two-price OER contract gives us an expected payoff of $J\pi^* = 4/27 > \pi_{MS}^{ex-ante}$. This example shows that if parties negotiate *ex ante*, even a simple fixed-term contract could outperform the optimal interim contingent contract.

³⁷ But here the revenue is not going to some third party as in a standard auction, it goes to the losing bidder in what Ayres and Balkin called "internal" auction. Ayres and Balkin (1996) applied a similar idea to a nuisance setting, in which the court can set multiple rounds of taking costs to induce efficient taking. We study parties' ex ante contracting under a multiple-round option remedy, while Ayres and Balkin (1996) focus on courts' design of liability rules. Also another difference is that we showed that even with two-sided uncertainty and asymmetric information, a simple ex ante contract can still replace a contingent contract to achieve efficient outcome asymptotically.

private valuations and decide whether to breach or not according to the rule they stipulated in the contract. Specifically, the remedy is characterized by n -round sequential options. We will assume first that n is an even number, i.e., we will have $n/2$ times of Option-to-Enforce games, where the prices and damages are different in every round. (The case of n being an odd number, where the seller unilaterally decides whether to breach in the *last* round, can be analyzed in a similar way, which we will show below).

The parties stipulate the initial price to be $p_0^{(n)}$.³⁸ In the first round the seller has an option to breach by paying damages $d_1^{(n)}$; and subsequently the buyer has an option to insist on performance by paying a higher (than original price $p_0^{(n)}$) price $p_1^{(n)}$; then at third round, the seller has an option to breach by paying a higher level of damages $d_2^{(n)}$; at fourth round, the buyer has an option to insist on performance by paying an even higher price $p_2^{(n)}$;.....; and so on, until to the final round n , where the buyer can agree to breach by receiving damages $d_{n/2}^{(n)}$, or insist on performance by paying price $p_{n/2}^{(n)}$. We assume there is no discounting between rounds.³⁹

As before the results are applicable to the general scenario where the parties share the bargaining power, for instance, the buyer receives a fraction $\theta \in [0,1]$ of the total surplus, and the seller obtains the remainder. For expositional simplicity, however, we will keep the assumption that the buyer has all of the bargaining power. Therefore, the buyer will offer the seller at time 0 a take-it-or-leave-it contract $(p_0^{(n)}, \{p_i^{(n)}\}, \{d_i^{(n)}\})_{i=1,2,\dots,(n/2)}$. Then at Time 1, after the parties have learned their private information, they will exchange the breach and insistence-on-performance messages, with the corresponding price and damage as stipulated in the contract.

As we saw when we discussed the Two-Price OER contract, the parties will not decide whether to exercise their options simply based on the price and damages level. Sometimes even if they suffer a loss in a specific round by exercising the option in that round, they might still do so in order to gain some profit from the following subgame. This is because the price and damages are increasing every round and because there is

³⁸ The superscript (n) indicates the values for an n -round sequential-option contract.

³⁹ Actually, playing the game is not as difficult as it may first look because the game is just a simple message-exchange, which can be accomplished in a short time through n emails.

some probability that the other party will exercise back his/her option in the next round, meaning the loss in the current round might be offset in the following round. This is the strategic overbidding that the sequential option game induces. Knowing this strategic incentive, it will be convenient to first pin down the optimal threshold values in every round; whenever the party's value is beyond the threshold value, he/she will exercise the option in that round. We denote $k_j^{(n)}$ as the threshold value of round i in an n th-order sequential option remedy regime, for $j=1,2,\dots,n$. The buyer seeks to design a sequence of p and d to induce the parties' optimal option-exercising behavior that will maximize the joint expected surplus.

We will delegate the derivation of the optimal values in the appendix. By maximizing the joint payoff, we get the optimal threshold values,

$$k_j^{(n)*} = j/(n+1), \quad \text{for } j=1,2,\dots,n; \quad (5.1)$$

Then in solving the parties' individual payoff maximization problems, we find the optimal prices and damages that will induce the parties to choose the above optimal threshold values,

$$p_i^{(n)*} = 2i/[3(n+1)] + p_0^{(n)}; d_i^{(n)*} = (n+2i)/[3(n+1)] - p_0^{(n)}, \quad i=1,2,\dots,n/2. \quad (5.2)$$

Where the $p_0^{(n)}$ is chosen to allocate the surplus between the two parties. Under our assumption that the buyer has all bargaining power,

$$p_0^{(n)*} = (7n^3 + 18n^2 + 17n + 9)/[18(n+1)^3]. \quad (5.3)$$

Remarks. (a) The optimal threshold values are an equal-distance series. This is an artifact of our assumption of uniform distributions.

(b) If n is an odd number, the expected joint payoff is,

$$\begin{aligned} J\pi^{(n)} &= k_1^{(n)}[(1/2) - E(c/c \leq k_1^{(n)})] \\ &+ (k_3^{(n)} - k_1^{(n)})(1 - k_2^{(n)})[E(v/v \geq k_2^{(n)}) - E(c/k_1^{(n)} < c < k_3^{(n)})] \\ &+ \dots + (k_n^{(n)} - k_{n-2}^{(n)})(1 - k_{n-1}^{(n)})[E(v/v \geq k_{n-1}^{(n)}) - E(c/k_{n-2}^{(n)} < c < k_n^{(n)})]; \end{aligned}$$

and the optimal solution is the same as when n is an even number.

(c) The equilibrium joint payoff is $J\pi^{(n)*} = \frac{n(n+2)}{6(n+1)^2}$. It is obvious that when

$\lim_{n \rightarrow \infty} J\pi^{(n)*} = 1/6$, which is the first-best joint payoff ($\int_0^1 \int_0^v (v-c)dc dv = 1/6$).

Therefore, the parties can sign a simple fixed-term sequential-option contract, $(p_0^{(n)*}, \{p_i^{(n)*}\}, \{q_i^{(n)*}\})_{i=1,2,\dots,(n/2)}$, defined by (5.2) and (5.3), at Time 1, and it can approach the first best when we have sufficient number of rounds.

Proposition 4 *An n th-order sequential option contract approaches first best efficiency when n goes to infinity.*

Figure 6 illustrates how the higher-order sequential-option remedy enhances efficiency. With n different threshold values which partition the valuation space, the inefficiency areas are reduced to many small triangles along the 45° line. In the limit, with infinitely many rounds of sequential options, the triangular inefficiency areas converge to points on the 45° line, and the allocation attains first best.

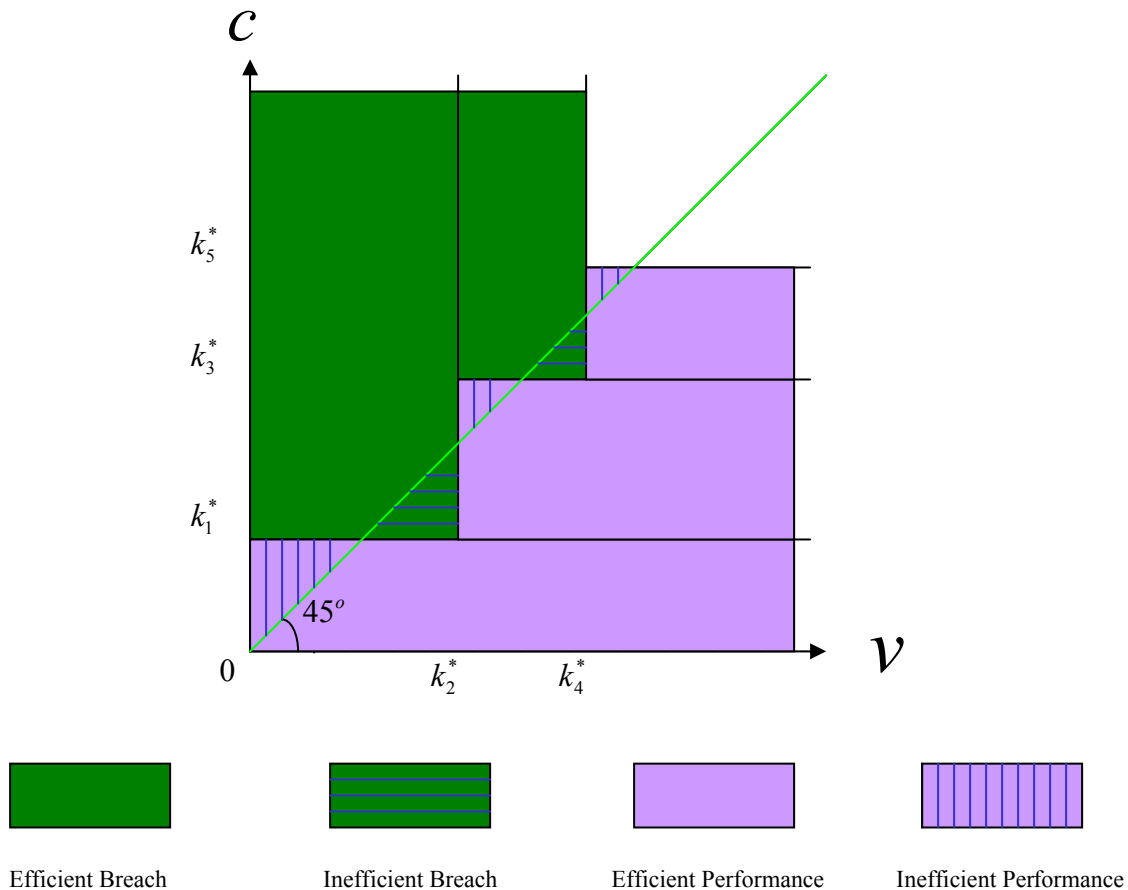


Figure 6 Higher-Order Sequential-Option Remedies

Remark: (a) It is well known that asymmetric information obstructs efficient trade, a la Myerson and Satterthwaite (1983). That “impossibility theorem” exists because of the difficulty in satisfying the ex post IR constraints. As there is a continuum of types, there is a continuum of IR constraints to be satisfied. Our contract in contrast approaches first best because the parties contract ex ante, and thus the continuum of IR constraints is reduced to a single ex ante IR constraint in expected terms. Indeed, as was shown by D’Aspremont, Gerard-Varet (1979), Konakayama, Mitsui and Watanabe (1986), and Rogerson (1992), an ex ante contract can attain first best. (Observe though that their contracts are all contingent-contracts, which are not usually seen in the real world.)

(b) Aghion, Dewatripont and Rey (1994) and Chung (1991), among others, demonstrated that a simple contract plus a renegotiation design can replicate a complex mechanism in inducing efficient trade and efficient investment. Their models, however, like others such as Hart and Moore (1988), assume that the information is observable, but not verifiable. In our model, in contrast, information is not observable. Yet, we were able to show that we can asymptotically approach first-best.

(c) Exactly how large n should be is a matter of taste. For instance, in our uniform distributions example, a four-round contract increases the joint surplus from $1/8$ (which was achieved in a single-round contract; also known as an RLR contract) to $4/25$. This is an increase of the joint surplus from 75% of the first-best to 96% of the first-best, in just few rounds.

(d) Observe that this simple fixed-term n -round contract essentially mimics the bargaining process, trying to force the parties to reveal some information, and thereby creating a finer partition of the parties’ information space. We know, however, that under asymmetric information bargaining often leads to multiple equilibria and inefficiencies. But our n -round contract is different from bargaining in several ways. Bargaining is unstructured, but our contract is structured ex ante. By stipulating in the contract, the parties have their option-exercising rights at their respective rounds. A party does not need to get an agreement from the other party before exercising his option, which is different from the consensual nature of bargaining.

(e) Through the option-exercising behavior, the private information is revealed gradually. It works like an ascending auction, where the parties submit bids (prices and damages in our case) for the right of performance. But unlike a typical auction, here the revenue will not go to some third party; it will go to the losing bidder.

(f) Our result can be applied to general distributions. Assuming $c \sim F(c)$ on $[\underline{c}, \bar{c}]$, $v \sim G(v)$ on $[\underline{v}, \bar{v}]$, where F and G are independent and common knowledge. Then, as before, we first obtain the optimal threshold values $\{k_i^{(n)*}\}_{i=1,2,\dots,n}$ by maximizing the joint surplus,

$$\begin{aligned} J\pi^{(n)} = & F(k_1^{(n)})[E(v) - E(c/c \leq k_1^{(n)})] \\ & + (F(k_3^{(n)}) - F(k_1^{(n)}))(1 - G(k_2^{(n)}))[E(v/v \geq k_2^{(n)}) - E(c/k_1^{(n)} < c < k_3^{(n)})] \\ & + \dots + (F(k_{n-1}^{(n)}) - F(k_{n-3}^{(n)}))(1 - G(k_{n-2}^{(n)}))[E(v/v \geq k_{n-2}^{(n)}) - E(c/k_{n-3}^{(n)} < c < k_{n-1}^{(n)})] \\ & + (1 - F(k_{n-1}^{(n)}))(1 - G(k_n^{(n)}))[E(v/v \geq k_n^{(n)}) - E(c/c > k_{n-1}^{(n)})]. \end{aligned}$$

In any given round whenever a party's valuation is above the threshold value, he/she will exercise the option at that round; otherwise the party will not exercise the option.

Then to obtain the optimal prices and damages, we need to assume that prices and damages are given and that parties maximize their individual payoffs by choosing optimal threshold values. The marginal conditions will give us a group of equations linking the threshold values and prices/damages; then by substituting the optimal threshold values in, we can get the optimal prices and damages.

5.2 Continuous Case and Implementation

For general distribution we can show that more rounds are better than fewer rounds, because with more rounds more information will be revealed through the option-exercising decisions. Thus, the allocative inefficiencies can be reduced. Though the n -round sequential option remedy effectively allows the contract to approach first-best, some may claim that the process is too cumbersome, although in fact it is actually a simple message-exchange game⁴⁰. Interestingly, we have recently found that Knysh,

⁴⁰ After the parties learned the information, they can exchange emails like "I want to exercise the option in this round", so just through n simple emails of "Yes/No" they will reach the last round.

Goldbart and Ayres (2004) extended the idea of higher-order liability rules (a legal regime which they apply to a stylized nuisance dispute) to the continuous type case. Extending work done by Ayres and Goldbart (2001) and Avraham (2004) KGA observed that there is no need for many intermediate steps for their liability regime to work.⁴¹ In a continuous setting, all n rounds can be reduced to a one-shot auction, where the parties submitted their maximum bids (b_S, b_B) for the entitlement, and the court will allocate the entitlement to the highest bidder, asking him to pay the loser damages, which are functions of the submitted bids $(p(b_B), d(b_S))$. They show that for general distributions with arbitrary correlations, a class of mechanisms, $(A, p(b_B), d(b_S))$, with A being a constant which can be used for distributing the surplus between the parties, can achieve first-best. They further show that such a mechanism is incentive compatible, i.e., the parties will submit their true valuations.

KGA's result is easily implemented and robust to correlated valuations.⁴² As KGA admit, their result is not a challenge to Myerson and Satterthwaite (1983), because they ignore the IR constraint in their analysis by assuming that the parties are already in the game. While KGA's work was applied to non-contractual relationships between a polluter and a pollutee, it is straight forward to extend KGA's mechanism to our ex ante contracting environment. One can use KGA's mechanism to implement an n-round sequential option contract in a one-shot auction, in which it can attain first-best efficiency. It is also incentive compatible and individually rational. The key is that while their parameter A is not sufficient to satisfy a continuum of ex post IR constraints, it is sufficient to satisfy a single ex ante IR constraint.

Proposition 5 *Through an instantaneous liability rule auction, we can achieve first-best with IR, IC satisfied.*

⁴¹ In Ayres and Goldbart (2001) and Avraham (2004) courts determine the magnitude of damages, whereas here the parties do that ex-ante via the liquidated damages clause. More importantly, Ayres and Goldbart (2001) and Avraham (2004) consider a nuisance dispute where parties are already in a relationship, and therefore there is no need to consider the ex-ante incentives to participate (the IR constraint). Here, in contrast, we explore possible remedies in case of a contract dispute and not a nuisance dispute and therefore we do emphasize the IR constraint at the ex-ante stage.

⁴² Hermalin and Katz (1993)'s "fill-in-the-price" mechanism, for example, doesn't work for imperfectly correlated distributions

Proof: In the appendix.

QED.

Remark: D' Aspremont, and Gerard-Varet (1979), Konokayama, Mitsui and Watanabe (1986), and Rogerson (1992) also can implement the continuous solution for uncorrelated distributions. KGA, however, showed that the first best can be achieved for very general correlated distributions with an infinite number of rounds. Actually, at the interim stage with parties having asymmetric information before bargaining as in Myerson and Satterthwaite (1983), McAfee and Reny (1992) have shown that even a very small correlation between the parties' values can eliminate the informational rent, and thus restore the first-best efficiency.

6. Summary and Future Research

In this paper we showed that with two-sided uncertainty and asymmetric information parties can still do quite well through simple fixed-term contracts than was previously thought. There is an intrinsic tension between, on the one hand, letting parties determine their remedies at the time they enter the contract and, on the other hand, letting the court make use of the information that has been revealed by the time of the breach. Our approach tries to take advantage of the good in both approaches. We suggest allowing the parties to postpone choosing a remedy until they have already learned the new information. In this way we keep the choice of remedy in the parties' hands, and we allow them to take advantage of the new information revealed to them at their time of the breach.

A regime which allows the parties to agree, if they wish, to give the buyer the option to enforce the contract (or get actual damages) is superior to both a legal regime of specific performance as well as to the current damage regime which restricts this option. From a doctrinal perspective, our analysis indicates that courts should enforce parties' contracts, whether the liquidated damages clause is *exclusive* or *optional* to other remedies such as specific performance or damages. Thus, to the extent that the current law restricts such options, it should be modified. Moreover, we believe that the proposed contract clauses will likely be enforced by courts, especially if the new proposed changes

in the UCC will be accepted. The new UCC is more liberal in enforcing liquidated damages clauses and specific performance clauses than the current UCC. We thus estimate that under the new UCC courts will be more likely to respect a clause which allows the aggrieved party to choose upon breach whether she prefers the liquidated damages or performance.

The OER regime, while improving upon the current regime, does not achieve first best, but on average it achieves only about 90% of it. We thus extended our model to a contract that includes a higher-order sequential option, which we showed can approach first best even in the environment of double-sided asymmetric information. Our extension resonates with the result that a simple contract with renegotiation can replace a more complex contingent contract, as shown in Chung (1991), and Aghion, Dewatripont and Rey (1994). In their models, the valuations are observable (though not verifiable), so efficient renegotiation is feasible. In our model, the information is kept private even after the resolution of uncertainties, erecting an insurmountable hurdle to efficient bargaining. With the strong information-revealing property of the sequential option contract, however, first best still can be approached with a simple fixed-term contract.

There are several issues that we leave for future research. First, our model can be extended to analyze different information structures. Second, our model can be extended to account for renegotiation between the seller and the buyer. Third, one can study optimal investment decisions, given our, or any other, information structure. Following Che and Hausch (1999), we believe that both self-investments and cooperative-investments are worth exploring. Fourth, it will be interesting to follow-up on the literature which accounts for third-party entrants. On this point, it is interesting to note that Chung (1992), for example, analyzed a case where the third-party's offer is observable to the original buyer and seller, but is not verifiable by the courts. He showed that if the potential entrant, the third party, has some bargaining power, first best cannot be obtained. Chung assumed no renegotiation in his model and restricted his attention to one-sided uncertainty. Spier & Whinston (1995) studied an environment where the buyer's value, the seller's cost and the entrant's offer are observable to all parties; the only uncertainty arises from the entrant's offer. In that information structure one can safely assume, as Spier and Whinston did, that efficient renegotiation is feasible.

Efficient renegotiation is certainly more difficult to attain when all parties have private information, as in our model. Lastly, Hua 2003 studied an ex-ante contract between a buyer and a seller which essentially provides the buyer some strategic advantage against a potential new buyer who later arrives. Hua showed that the original buyer and seller can jointly extract rent from the new buyer, but that it can nevertheless be more socially efficient than the absence of such contract because it mitigates the seller's ex-post rent seeking vis-à-vis the original buyer. Hua's model, however, assumes one sided-uncertainty and no renegotiation or investments.

7. Appendix

7.1 General

The appendix collects the proofs of Lemma 3 and Proposition 1 and some numerical comparative statics.

The following is a standard *Monotone Hazard Rate* assumption we will use in our analysis:

Assumption A1 $[1 - F(x)]/f(x)$ and $g(x)/G(x)$ are decreasing in x .

Superscripts O (R) denote values under OER (RLR) in the liquidated damages model; while subscripts B(S) denote values for the buyer (seller).

7.2 Proof of Lemma 3

Lemma 3

If $g(E(v))[1 - F(E(v))][E(c/c \geq E(v)) - E(v)] < f(E(v))G(E(v))[E(v) - E(v/v \leq E(v))]$, then $k_o^* < E(v)$.

Proof: The first order condition, (2.3), can be rewritten as:

$$\begin{aligned} \Gamma(k_o^*) &= -f(k_o^*)G(k_o^*)(k_o^* - \int_v^{k_o^*} v dG(v)/G(k_o^*)) + g(k_o^*)[1 - F(k_o^*)][\int_{k_o^*}^{\bar{c}} c dF(c)/[1 - F(k_o^*)] - k_o^*] \\ &= g(k_o^*)[1 - F(k_o^*)][E(c/c \geq k_o^*) - k_o^*] - f(k_o^*)G(k_o^*)[(k_o^*) - E(v/v \leq k_o^*)] = 0 \end{aligned}$$

If $g(E(v))[1 - F(E(v))][E(c/c \geq E(v)) - E(v)] < f(E(v))G(E(v))[E(v) - E(v/v \leq E(v))]$, then $\Gamma(E(v)) < 0$. The second-order condition implies that $\Gamma' < 0$, hence we have $k_o^* < E(v)$. QED.

7.3 Lemma 4

Which legal regime, RLR or OER, will induce more breach is not clear. Lemma 4 determines the conditions under which OER will induce less breach than RLR.

Lemma 4 *If $k_o^* \geq E(v)$, then the OER contract induces less expected breach than RLR does.*

Proof: Under RLR, if $c > k_r^* = E(v)$, i.e., with probability $1 - F(E(v))$ the seller will breach. Under OER, the seller actually breaches only if $c > k_o^*$ and $v < k_o^*$. This happens with probability $[1 - F(k_o^*)]G(k_o^*)$. $k_o^* \geq E(v)$ implies that $[1 - F(k_o^*)]G(k_o^*) \leq [1 - F(E(v))]G(k_o^*) < 1 - F(E(v))$.

7.4 Proof of Proposition 1

Lemma 1 and 2 imply that:

$$\begin{aligned}
\pi_o^{B^*} - \pi_r^{B^*} &= F(k_o^*)E(v) - E(c) + G(k_o^*) \int_{k_o^*}^{\bar{c}} cdF(c) \\
&\quad + [1 - F(k_o^*)] \int_{k_o^*}^{\bar{v}} vdG(v) - F(E(v))E(v) + \int_{\underline{c}}^{E(v)} cdF(c) \\
&= [F(k_o^*) - F(E(v))]E(v) - \int_{E(v)}^{\bar{c}} cdF(c) \\
&\quad + G(k_o^*) \int_{k_o^*}^{\bar{c}} cdF(c) + [1 - F(k_o^*)] \int_{k_o^*}^{\bar{v}} vdG(v) \tag{7.1}
\end{aligned}$$

Proposition 1 *In a regime of double-sided uncertainty where parties specific performance and liquidated damages clauses are honored, OER is Pareto superior to RLR, if $E(v/v \geq E(v)) > E(c/c \geq E(v))$ and $E(v/v \leq E(c)) > E(c/c \leq E(c))$.*

Proof: We first prove for the case of the seller initiating breach. Let $k_o = E(v), p_o = x$, then the seller's expected payoff is:

$$\begin{aligned}\pi_o^S \Big|_{k_o=E(v), p_o=x} &= [1 - G(E(v)) + F(E(v))G(E(v))]x \\ &\quad - [1 - F(E(v))]G(E(v))[E(v) - x] - E(c) + G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c) \\ &= x - E(c) + G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c) - [1 - F(E(v))]G(E(v))E(v)\end{aligned}$$

Let $\pi_o^S = 0$, we have $p_o = E(c) - G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c) + [1 - F(E(v))]G(E(v))E(v)$. Since

this price plus $d_o = E(V) - p_o$ guarantees the seller's expected payoff is zero, it is a feasible contract. Plugging this specific contract into the buyer's payoff function and simplifying, we get

$$\begin{aligned}\pi_o^B \Big|_{p_o=E(c)-G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c)+[1-F(E(v))]G(E(v))E(v), d_o=E(v)-p_o} &= F(E(v))E(v) + [1 - F(E(v))] \int_{E(v)}^{\bar{v}} vdG(v) - E(c) + G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c)\end{aligned}$$

and we have

$$\begin{aligned}\pi_o^B \Big|_{p_o=E(c)-G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c)+[1-F(E(v))]G(E(v))E(v), d_o=E(v)-p_o} &\quad - \pi_R^{B*} \\ &= F(E(v))E(v) + [1 - F(E(v))] \int_{E(v)}^{\bar{v}} vdG(v) - E(c) + G(E(v)) \int_{E(v)}^{\bar{c}} cdF(c) \\ &\quad - F(E(v))E(v) + \int_{\underline{c}}^{E(v)} cdF(c) \\ &= [1 - F(E(v))] \int_{E(v)}^{\bar{v}} vdG(v) - [1 - G(E(v))] \int_{E(v)}^{\bar{c}} cdF(c) \\ &= [1 - F(E(v))][1 - G(E(v))][E(v/v \geq E(v)) - E(c/c \geq E(v))] > 0\end{aligned}$$

By the optimality of p_o^* and d_o^* , we have

$$\pi_O^{B*} = \pi_O^B \Big|_{p_O^*, d_O^*} \geq \pi_O^B \Big|_{p_O = E(c) - G(E(v)) \int_{E(v)}^{\bar{c}} c dF(c) + [1 - F(E(v))] G(E(v)) E(v), d_O = E(v) - p_O}, \text{ therefore,}$$

$$\pi_O^{B*} - \pi_R^{B*} \geq \pi_O^B \Big|_{p_O = E(c) - G(E(v)) \int_{E(v)}^{\bar{c}} c dF(c) + [1 - F(E(v))] G(E(v)) E(v), d_O = E(v) - p_O} - \pi_R^{B*} > 0 \quad \text{if}$$

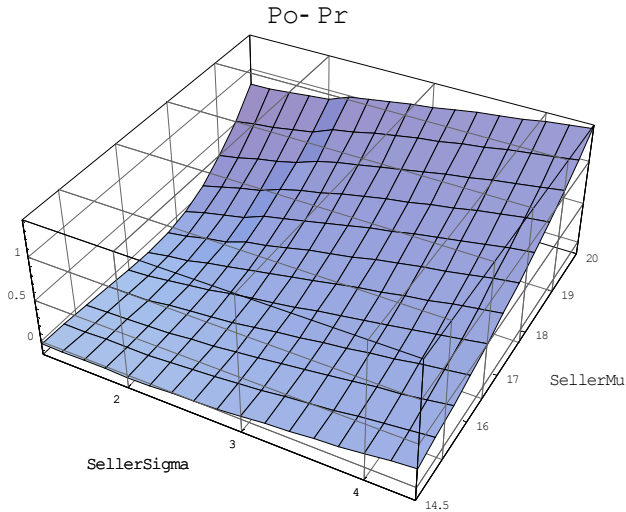
$$E(v/v \geq E(v)) > E(c/c \geq E(v)).$$

The condition for the buyer-breach case can be proved similarly. *QED.*

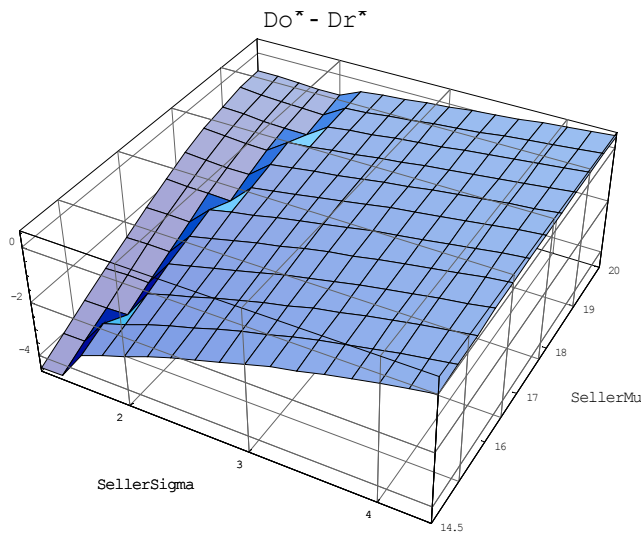
7.5 Comparative Statics

7.5.1 A Comparison of the Price and Damages under two Contracts.

Our numerical model enables us to take a closer look at the specific price and damage clauses that the parties will agree on. Consider first the different prices that OER and RLR contracts will have. A buyer's subsequent option to enforce makes the seller worse off under the same price and damage term because he loses the power to unilaterally breach. Thus, one would expect that the buyer will "compensate" the seller for the switch from an RLR contract to an OER contract, either by offering a higher price or by allowing the seller to pay lower damages in case of a breach, or any combination the two. Indeed, our numerical example confirms this intuition. The buyer will "bribe" the seller to switch from the RLR to OER contract, with either a higher price, lower damages, or both. Graphs 2a and 2b present the results.



Graph 2a- A Comparison of the Contract Price.



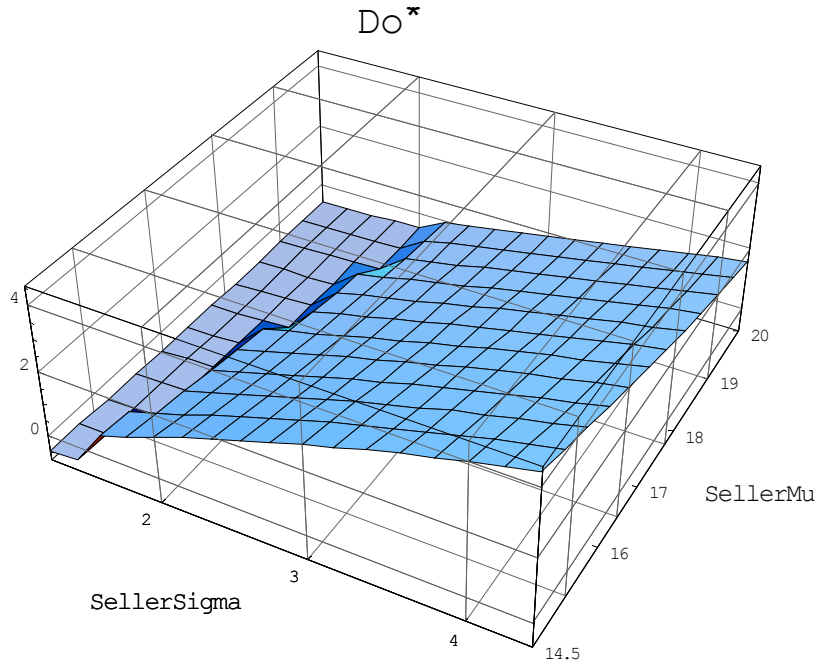
Graph 2b- A Comparison of the Contract Damages.

Graph 2a shows that in general the OER contract price is higher, except for a very small area where the seller's sigma is extremely small and his mean is relatively large. Graph 2b shows that, in general, the damages in the OER contract are smaller, except for a very small area where both seller's sigma and mean are very large.⁴³ Thus, for every possible iteration of the seller's costs and the buyer's valuation, the OER contract provides the seller with either a higher price, or lower damages, or both.

7.5.2 The Case of Negative Damages.

⁴³ The reader should recall the Seller's maximum mean is equal to the buyer's mean.

An interesting result of our research is that sometimes parties will agree on *negative* damages under the single price OER contract. Graph 3 presents it.



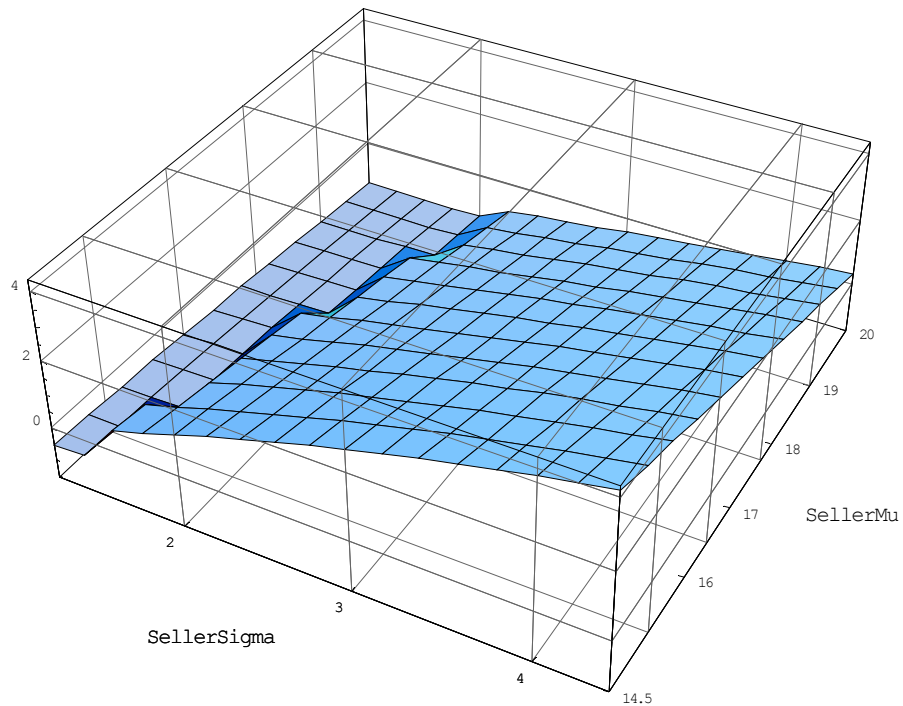
Graph 3- The Stipulated Damages in an OER contract.

As graph 3 shows, when the seller’s sigma is relatively small, the stipulated damages that the seller will have to pay in case of a contract breach are negative. That is, in these circumstances, when the seller considers to breach the contract, the buyer might well agree to *pay* to the seller the predetermined stipulated amount in order to prevent the seller from performing and secure a breach.⁴⁴

To understand the intuition for this result we first have to observe two facts. First, for low sigmas the seller’s optimal breach threshold, k_o^* , is always smaller than the seller’s mean. That is, for low sigmas we observe that: $k_o^* < E[c]$. Graph 4 presents this result.

⁴⁴ Compare to Ayres & Madison, 2000.

Breach-Threshold - Seller's Mean Costs



Graph 4- The Stipulated Damages in an OER contract minus $E[c]$.

As Graph 4 shows, for a low seller's sigma the breach threshold, k_o^* , minus the seller's mean, $E[c]$, is negative. This fact indicates that from the ex-ante perspective the seller's ex-post costs are most likely to exceed in these cases the breach threshold, k_o^* .⁴⁵ This means that more likely than not, a seller with a low sigma will attempt to breach because his costs are higher than the breach threshold.

However, the buyer's mean, for most parts, is larger than the seller's mean. Thus, from the ex-ante perspective the buyer's ex-post valuation is, too, most likely to exceed the breach threshold. This means that the buyer will most likely insist on performance in these cases.

To summarize, under the OER contract in cases of a seller with a low sigma, the seller will most likely want to breach, and the buyer will most likely insist on performance.

⁴⁵ There is a 50% chance that seller's costs will be higher than his mean. Thus, there is more than 50% chance that his costs will be higher than k_o^* which is smaller than seller's mean (for low sigmas).

The second fact to observe is that the price the buyer offers in the OER contract, p_o^* , is also always smaller than the seller's mean (no matter what the seller's sigma is).⁴⁶ This fact indicates that the seller gets a price, p_o^* , which does not cover his expected costs for a contract which he will most likely have to perform. A risk neutral seller might of course not agree to such a contract in the first place. To make it individually rational for the seller to agree to such a contract, the buyer must promise the seller *negative* damages.

But under what circumstances would the buyer be willing to pay negative damages? Sometimes the buyer's ex-post valuation will be so low that she will prefer to pay the seller *not* to perform. She will prefer this option on the alternative, which is to pay the full price p_o^* for a good for which her valuation is so low. From the seller's perspective, the possibility for this rare expected profit in cases of a breach somewhat makes up for the more likely expected loss from performance.

7.6 The Two-Price Contract.

We assume that the buyer offers a take-it-or-leave-it contract $(p_o, p_o + \Delta, d_o)$ to the seller. The buyer will insist on performance if $v \geq p_o + d_o + \Delta$ and will agree to the breach otherwise. If the seller performs, he will receive a payoff of $p_o - c$; if he attempts to breach the contract, his expected payoff is $G(p_o + d_o + \Delta)(-d_o) + [1 - G(p_o + d_o + \Delta)](p_o + \Delta - c)$. Hence, the seller will perform if $c \leq p_o + d_o + \Delta - [\Delta / G(p_o + d_o + \Delta)]$, and will attempt to breach otherwise.

We denote the seller's breach threshold as $p_o + d_o + \Delta - [\Delta / G(p_o + d_o + \Delta)] \equiv k_1$, and the buyer's threshold as $p_o + d_o + \Delta \equiv k_2$. Viewing sequential option exercising as an internal, ascending auction process, we can see from the expression of k_1 that the seller

⁴⁶ To see this, observe that if the contract restricted the remedy to always being specific performance, then to keep the Seller's expected payoff equal to zero, the buyer must have offered a price equal to the Seller's mean costs. Since in the OER contract there are some cases where the Seller can avoid performance, the buyer can offer a lower price.

will strategically overbid (with a term of $\Delta/G(p_o + d_o + \Delta)$) in the first round, trying to receive a higher price from the buyer in the next round. The buyer's expected payoffs is:

$$\pi_o^B = F(k_1)[E(v) - p_o] + [1 - F(k_1)]\{G(k_2)d_o + [1 - G(k_2)][E(v|v \geq k_2) - p_o - \Delta]\}.$$

The seller's expected payoffs is:

$$\pi_o^S = F(k_1)[p_o - E(c|c \leq k_1)] + [1 - F(k_1)]\{G(k_2)(-d_o) + [1 - G(k_2)][p_o + \Delta - E(c|c \geq k_1)]\}.$$

As before the buyer will maximize the joint payoff, then manipulate p_o to extract all surplus from the seller. The buyer's problem is:

$$\text{Max}_{\{p_o, d_o, \Delta\}} \pi_o^B + \pi_o^S = F(k_1)E(v) - E(c) + [1 - F(k_1)] \int_{k_2}^{\bar{v}} v dG(v) + G(k_2) \int_{k_1}^{\bar{c}} c dF(c).$$

The first-order conditions are:

For p_o or d_o :

$$f(k_1)[1 + \Delta g(k_2)/G^2(k_2)] \left[\int_{\underline{v}}^{k_2} v dG(v) - k_1 G(k_2) \right] + g(k_2) \left\{ \int_{k_1}^{\bar{c}} c dF(c) - k_2 [1 - F(k_1)] \right\} = 0, \quad (7.2)$$

For Δ :

$$\begin{aligned} & f(k_1) \left[1 - \frac{1}{G(k_2)} + \Delta g(k_2)/G^2(k_2) \right] \left[\int_{\underline{v}}^{k_2} v dG(v) - k_1 G(k_2) \right] \\ & + g(k_2) \left\{ \int_{k_1}^{\bar{c}} c dF(c) - k_2 [1 - F(k_1)] \right\} = 0. \end{aligned} \quad (7.3)$$

Subtracting (7.3) from (7.2) gives us

$$\Delta = \int_{\underline{v}}^{k_2} G(v) dv \quad (7.4)$$

It is easy to verify that $p_o^* + d_o^* + \Delta^* > \underline{v}$.⁴⁷ Equation (7.4) implies that $\Delta > 0$, which means that the buyer will never choose the Single-Price contract, despite seller's strategic behavior.

⁴⁷ If $p_o^* + d_o^* + \Delta^* \leq \underline{v}$, then the buyer will always insist on performance, and the two-price Option-to-Enforce contract is equivalent to specific performance, which is a regime that ignores parties' private information. This regime is less efficient than RLR (or OER) which take advantage of the parties' private information. However, we can simply construct a feasible two-price Option-to-Enforce contract that is equivalent to RLR--- $p_o = p_R, d_o = d_R, p_o + \Delta = \bar{v}$. Therefore, $p_o^* + d_o^* + \Delta^* > \underline{v}$.

Equations (7.3) and (7.4) imply:

$$k_2 = E(c|c \geq k_1) = E\left(c \geq k_2 - \frac{\Delta}{G(k_2)}\right), \quad (7.5)$$

The assumption that the buyer makes a take-it-or-leave-it offer implies:

$$\pi_o^S = p_o - E(c) + [1 - F(k_1)][\Delta - k_2 G(k_2)] + G(k_2) \int_{k_1}^{\bar{c}} c dF(c) = 0. \quad (7.6)$$

From equations (7.4)-(7.6), we can solve for p_o^* , d_o^* , and Δ^* . And we have Proposition 3.

7.7 The Desirability of the Ex-Ante Contract.

Before we demonstrate this claim, it is useful to recall that scholars applying the mechanism design approach largely agree that parties cannot achieve the first best in the interim stage (Myerson & Satterthwaite (1983), Talley (1994)), but they *can* achieve it in the ex-ante stage (D'Aspremont & Gerard-Varet (1979)), even when parties' investments are required (Rogerson (1992), Che & Hausch (1999)). This means that when contingent contracts are feasible meeting at the ex-ante stage is superior to meeting at the interim stage even though more information is on the table at the interim stage. Does that result carry to the non-contingent contracts world?

To check whether or not the simple ex-ante contract we described above is superior to a contract designed in the interim stage, we compared the joint expected payoff in both contracts. To compute the joint payoff in the interim stage, one has to determine what type of bargaining game the parties will play when they meet at that stage. In general, the more sophisticated the bargaining game, the higher the joint payoff will be. To test the desirability of the ex-ante contract, we compare it to the second-best.

The Second-Best Interim Contract

The second -best interim contract is the best contract achievable under asymmetry of information a-la Myerson & Satterthwaite. Based on their formulation we compute the second-best joint payoff without specifying the bargaining game. Thus, we get the joint

payoff for the best of all possible contracts in the interim stage. This will serve as the upper bound of joint payoff at the interim stage.

To compute the joint payoff of second-best contract we followed Myerson and Satterthwaite (1983). We first defined:

$$c(c, \alpha) = c + \alpha F(c) / f(c); \quad v(v, \alpha) = v - \alpha[1 - G(v)] / g(v). \quad (7.7)$$

Then we let $p^\alpha(.,.)$ be defined by

$$p^\alpha(c, v) = \begin{cases} 1 & \text{if } c(c, \alpha) \leq v(v, \alpha), \\ 0 & \text{if } c(c, \alpha) > v(v, \alpha). \end{cases} \quad (7.8)$$

We then numerically computed α from the equation (7.9):

$$\int_{\underline{v}}^{\bar{v}} \int_{\underline{c}}^{\bar{c}} \left(\left[v - \frac{1 - G(v)}{g(v)} \right] - \left[c + \frac{F(c)}{f(c)} \right] \right) p^\alpha(c, v) dF(c) dG(v) = 0. \quad (7.9)$$

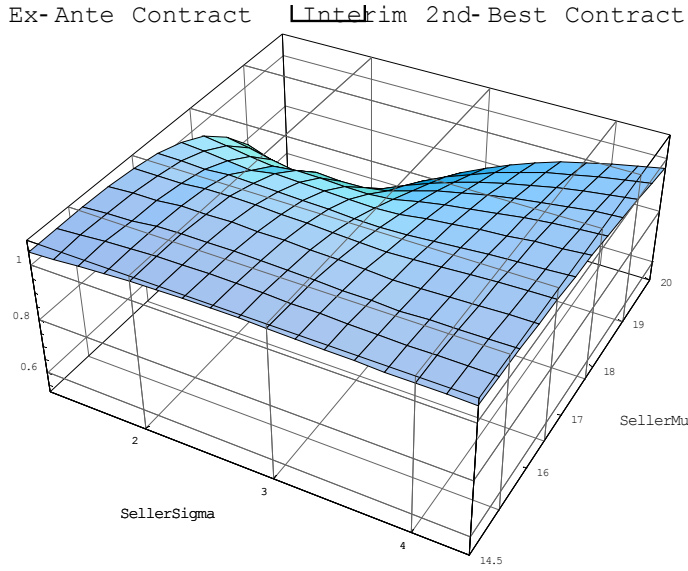
After we found α we plugged it back in (7.7) and (7.8) to find $c(c, \alpha)$, $v(v, \alpha)$ and $p^\alpha(c, v)$.

Lastly, we calculated the expected (ex ante) payoff of a Myerson-Satterthwaite contract is

$$E\pi_{ms} = \int_{\underline{v}}^{\bar{v}} \int_{\underline{c}}^{\bar{c}} (v - c) p^\alpha(c, v) dF(c) dG(v) \quad (7.10)$$

Graph 5 presents the ratio of the joint expected payoff of the interim contracts (from (7.10)) and the joint expected payoff of the best ex-ante contract. Before we discuss the results, we would like to define the “best ex-ante contract.” The “best ex-ante contract” is the contract that parties will enter at the ex-ante stage. It can be a RLR or an OER, depending on their relative valuations. While both the RLR and the OER yield on average higher joint payoff than the interim contract, the “best contract”, naturally, yields an even higher joint payoff.

Graph 5- The Ex-ante contract and the Second-Best Interim Contract



Graphs 5 shows that in general the best ex-ante contract is superior to the second-best contracts. There is an exception though. Whenever the seller’s mean is very close to the buyer’s mean, or larger than it, and seller’s sigma is relatively low, the parties would be better off to wait for the interim stage before they enter a simple fixed-terms contact.

7.8 The Derivation of Optimal Threshold Values, Prices and Damages under n-Round Sequential-Option Remedy

Observe that viewed though this framework, an RLR contract is a first-order option, under which the seller will breach whenever his cost is beyond $k_1^{(1)}$. In such a regime, the buyer will offer an optimal $k_1^{(1)}$ to maximize the joint payoff, which is,

$$J\pi^{(1)} = F(k_1^{(1)})[E(v) - E(c/c \leq k_1^{(1)})] = (1 - k_1^{(1)})k_1^{(1)} / 2.$$

The optimal $k_1^{(1)*} = 1/2$, i.e., the buyer will set expected expectation damages. This will lead to a joint surplus of $J\pi^{(1)*} = 1/8$.

Next observe that a two-price OER is simply a second-order sequential option, under which the seller will attempt to breach in the first round whenever his costs are above $k_1^{(2)}$, and the buyer will insist on performance in the second round if her valuation is above $k_2^{(2)}$. The expected joint payoff is,

$$J\pi^{(2)} = F(k_1^{(2)})[(1/2) - E(c/c \leq k_1^{(2)})] \\ + [1 - F(k_1^{(2)})][1 - G(k_2^{(2)})][E(v/v \geq k_2^{(2)}) - E(c/c \geq k_1^{(2)})].$$

The optimal $k_1^{(2)*} = 1/3, k_2^{(2)*} = 2/3, J\pi^{(2)*} = 4/27$.

In a third-order sequential option contract, there is an additional round after the buyer insists on performance in which the seller will breach if his cost is beyond $k_3^{(3)}$.

The joint expected payoff is,

$$J\pi^{(3)} = F(k_1^{(3)})[(1/2) - E(c/c \leq k_3^{(3)})] \\ + [F(k_3^{(3)}) - F(k_1^{(3)})][1 - G(k_2^{(3)})][E(v/v \geq k_2^{(3)}) - E(c/k_1^{(3)} < c < k_3^{(3)})].$$

The optimal $k_1^{(3)*} = 1/4, k_2^{(3)*} = 1/2, k_3^{(3)*} = 3/4, J\pi^{(3)*} = 5/32$.

More generally, under an n th-order sequential option remedy regime the joint expected payoff (if n is an even number) is,

$$J\pi^{(n)} = k_1^{(n)}[(1/2) - E(c/c \leq k_1^{(n)})] \\ + (k_3^{(n)} - k_1^{(n)})(1 - k_2^{(n)})[E(v/v \geq k_2^{(n)}) - E(c/k_1^{(n)} < c < k_3^{(n)})] \\ + (k_5^{(n)} - k_3^{(n)})(1 - k_4^{(n)})[E(v/v \geq k_4^{(n)}) - E(c/k_3^{(n)} < c < k_5^{(n)})] + \dots \\ + (k_{n-1}^{(n)} - k_{n-3}^{(n)})(1 - k_{n-2}^{(n)})[E(v/v \geq k_{n-2}^{(n)}) - E(c/k_{n-3}^{(n)} < c < k_{n-1}^{(n)})] \\ + (1 - k_{n-1}^{(n)})(1 - k_n^{(n)})[E(v/v \geq k_n^{(n)}) - E(c/c > k_{n-1}^{(n)})].$$

The first-order conditions for $k_i^{(n)}$ give us the optimal threshold values,

$$k_j^{(n)*} = j/(n+1), \quad \text{for } j = 1, 2, \dots, n; \quad (7.11)$$

We now turn to explore what contract $(p_0^{(n)}, \{p_i^{(n)}\}, \{d_i^{(n)}\})_{i=1,2,\dots,(n/2)}$ can induce the optimal threshold values we calculated above. We solve this in a kind of reverse way by asking what threshold values the parties will take given a contract. Given the prices and damages, the seller will choose threshold values $(k_1^{(n)}, k_3^{(n)}, \dots, k_{n-1}^{(n)})$ to maximize his expected payoff, and the buyer will choose threshold values $(k_2^{(n)}, k_4^{(n)}, \dots, k_n^{(n)})$ to maximize her expected payoff.

By definition, at the margin of the threshold values⁴⁸ the party should get the same expected payoff by not exercising the option as the payoff he/she would receive by

⁴⁸ What we mean here is that if parties' valuations are above these values than parties will exercise their options. Parties will not exercise their options if their valuations fall below these threshold values.

exercising the option. Given prices and damages, the equilibrium conditions for optimal threshold values are as follows (assuming that n is an even number):

$$\begin{aligned}
k_1^{(n)}: & p_0^{(n)} - k_1^{(n)} = k_2^{(n)}(-d_1^{(n)}) + (1 - k_2^{(n)})(p_1^{(n)} - k_1^{(n)}), \\
k_2^{(n)}: & k_1^{(n)}(k_2^{(n)} - p_0^{(n)}) + (1 - k_1^{(n)})d_1^{(n)} = k_1^{(n)}(k_2^{(n)} - p_0^{(n)}) + (k_3^{(n)} - k_1^{(n)})(k_2^{(n)} - p_1^{(n)}) + (1 - k_3^{(n)})d_2^{(n)}, \\
k_3^{(n)}: & k_2^{(n)}(-d_1^{(n)}) + (1 - k_2^{(n)})(p_1^{(n)} - k_3^{(n)}) = k_2^{(n)}(-d_1^{(n)}) + (k_4^{(n)} - k_2^{(n)})(-d_2^{(n)}) + (1 - k_4^{(n)})(p_2^{(n)} - k_3^{(n)}), \\
& \dots, \\
k_{n-1}^{(n)}: & (1 - k_{n-2}^{(n)})(p_{(n/2)-1}^{(n)} - k_{n-1}^{(n)}) = (k_n^{(n)} - k_{n-2}^{(n)})(-d_{n/2}^{(n)}) + (1 - k_n^{(n)})(p_{n/2}^{(n)} - k_{n-1}^{(n)}), \\
k_n^{(n)}: & (1 - k_{n-1}^{(n)})d_{n/2}^{(n)} = (1 - k_{n-1}^{(n)})(k_n^{(n)} - p_{n/2}^{(n)}).
\end{aligned}$$

In any of the above equations, the left side is the party's expected payoff when he/she does not exercise the option; the right side is the party's expected payoff when he/she exercises the option.

Substituting the optimal threshold values, $k_j^{(n)*} = j/(n+1)$ ($j = 1, 2, \dots, n$), into the above equations and solving them, we get the optimal prices and damages:

$$p_i^{(n)*} = 2i/[3(n+1)] + p_0^{(n)}; d_i^{(n)*} = (n+2i)/[3(n+1)] - p_0^{(n)}, \quad i = 1, 2, \dots, n/2. \quad (7.12)$$

As explained before, parties can allocate the surplus according to their relative bargaining power through the initial price, $p_0^{(n)}$. In our example, where the buyer has all the bargaining power, the buyer will set $p_0^{(n)}$ such that the seller's expected payoff is zero. The seller's expected payoff is:

$$\begin{aligned}
\pi_s^{(n)} = & k_1^{(n)}[p_0^{(n)} - E(c/c \leq k_1^{(n)})] \\
& + (k_3^{(n)} - k_1^{(n)})[k_2^{(n)}(-d_1^{(n)}) + (1 - k_2^{(n)})(p_1^{(n)} - E(c/k_1^{(n)} < v < k_3^{(n)}))] \\
& + (k_5^{(n)} - k_3^{(n)})[k_4^{(n)}(-d_2^{(n)}) + (1 - k_4^{(n)})(p_2^{(n)} - E(c/k_3^{(n)} < v < k_5^{(n)}))] + \dots \\
& + (k_{n-1}^{(n)} - k_{n-3}^{(n)})[k_{n-2}^{(n)}(-d_{(n/2)-1}^{(n)}) + (1 - k_{n-2}^{(n)})(p_{(n/2)-1}^{(n)} - E(c/k_{n-3}^{(n)} < c < k_{n-1}^{(n)}))] \\
& + (1 - k_{n-1}^{(n)})[k_n^{(n)}(-d_{n/2}^{(n)}) + (1 - k_n^{(n)})(p_{n/2}^{(n)} - E(c/c \geq k_{n-1}^{(n)}))].
\end{aligned}$$

Substituting the optimal threshold values, prices, and damages into the equation, we have the reduced form of the seller's equilibrium expected payoff,

$$\pi_s^{(n)*} = p_0^{(n)} - (7n^3 + 18n^2 + 17n + 9)/[18(n+1)^3],$$

therefore, under the assumption that the buyer has all bargaining power,

$$p_0^{(n)*} = (7n^3 + 18n^2 + 17n + 9)/[18(n+1)^3]. \quad (7.13)$$

7.9 Proof of Proposition 5

Proposition 5 *Through an instantaneous liability rule auction, we can achieve first-best with IR, IC satisfied.*

Proof: The parties sign a KGA contract $(A, p(b_B), d(b_S))$ ex ante in which each party will submit a bid, b , to the court after he/she learned his/her valuations. Then by KGA, it will be incentive compatible and first-best efficient.

We denote a buyer of type v 's ex post payoff (excluding the constant A from the KGA contract) as $\pi^B(v)$; similarly, we denote a seller of type c 's ex post payoff (excluding the constant A from the KGA contract) as $\pi^S(c)$. Then by choosing A such that $A + \int_{\underline{c}}^{\bar{c}} \pi^S(c) dF(c) = 0$ we can make the contract satisfy IR constraints, because ex post the buyer will receive a payoff of $\pi^B(v) - A$, while the seller will receive a payoff of $\pi^S(c) + A$. It satisfies ex post collective IR, which is $\sum \pi = \pi^B(v) + \pi^S(c) \geq 0$;

The buyer's ex ante payoff is

$$\int_{\underline{v}}^{\bar{v}} \pi^B(v) dG(v) - A = \int_{\underline{v}}^{\bar{v}} \pi^B(v) dG(v) + \int_{\underline{c}}^{\bar{c}} \pi^S(c) dF(c) = \int_{\underline{v}}^{\bar{v}} \int_{\underline{c}}^{\bar{c}} \sum \pi dG(v) dF(c) \geq 0. \quad \text{QED.}$$

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