CONSTRUCTION CONTRACTS (OR "HOW TO GET THE RIGHT BUILDING AT THE RIGHT PRICE?")

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Abstract

Most contracts that individuals enter into are not written from scratch; rather, they depend upon forms and terms that have been successful in the past. In this paper, we study the structure of form construction contracts published by the American Institute of Architects (AIA). We show that these contracts are an efficient solution to the problem of procuring large, complex projects when unforeseen contingencies are inevitable. This is achieved by carefully structuring the ex post bargaining game between the Principal and the Agent. The optimal mechanism corresponding to the AIA construction form is consistent with decisions of the courts in several prominent but controversial cases, and hence it provides an economic foundation for a number of the common-law excuses from performance. Finally, the case of form contracts for construction is an example of how markets, as opposed to private negotiations, can be used to determine efficient contract terms.

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> Nowhere is the confusion between legal and moral ideas more manifest than in the law of contract. Among other things, here again the so-called primary rights and duties are invested with a mystic significance beyond what can be assigned and explained. The duty to keep a contract at common law means a prediction that you must pay damages if you do not keep it and nothing else.

Oliver Wendell Holmes (1897)

1 Introduction

The economic theory of contract typically assumes that, when the outcome from the exchange of a good is publicly observable, one can write a legally binding contract to enforce any feasible output or quality level. If parties can also contract over the *ex post* allocation of bargaining power, then it is possible to write a contract that simultaneously ensures efficient relationship specific investments and efficient risk sharing.[1] Yet, as Holmes (1897) observes, courts are limited in their ability to enforce performance, and they cannot in general enforce either the quantity or quality of a good trade. Rather, legally enforceable contracts structure the allocation of resources, normally monetary damages and real property, in such a way that they create *incentives* for the parties to make choices consistent with the original intent of their agreement. This paper introduces a model of complex exchange that can address the question of optimal contract design given the available legal instruments.

This is an important question because there is a growing body of research illustrating how the quality of contract enforcement can affect economic growth. The seminal work of North and Thomas (1973) discusses how decreases in the cost of contract enforcement encouraged economic growth in Europe.[2] Recent work by Acemoglu, Johnson, and Robinson (2001) and by Rodrik, Subramanian, and Trebbi (2004) has begun to illustrate empirically how institutions such as the legal system matter for economic growth. Djankov, La Porta, Lopez-de Silanes, and Shleifer (2003) provide evidence on the variations in the difficulty and cost of enforcing rental contracts between tenants and landlords across different countries and legal systems. They find that the style of legal system, namely, whether it has its origins in the common law traditions of England or in the continental civil law tradition, can affect economic growth.

We add to this literature by providing a detailed analysis of the specific, but very important, question of how to write an efficient construction contract. Construction contracts are interesting not only because they regulate a very large amount of economic activity (about 9% of US gross domestic product, or about $934 billion in 2003[3]) but also because they are a classic example of *complex exchange.* The plans for a large construction project are always incomplete, and hence parties must of necessarily provide a way to govern changes to the original plans.

[1] See Aghion, Dewatripont, and Rey (1994) and Chung (1991).

[2] See page 156.

[3] As estimated by the U.S. Census Bureau.

The problem of efficiently regulating complex exchange is the starting point for the property rights approach to the theory of the firm developed by Grossman and Hart (1986) and by Hart and Moore (1990). They show that one can use the instrument of *asset ownership* to allocate residual control rights in order to shape the incentives for relationship specific investments. We find that this insight is general, namely, we present evidence that construction contracts carefully structure the *ex post* allocation of residual contract rights. We then show that the solution observed in practice corresponds to an *efficient* contract given the set of legal instruments provided by the courts. Finally, we show that the property rights theory can provide a unified approach to the analysis of a class of legal default rules.

Specifically, we show that, depending upon the nature of the relationship specific investments, either cost plus or fixed price contracts, combined with a well defined governance structure for contract renegotiation, provide an efficient solution to the problem of building a large, complex building or engineering project. These results extend the results of Bajari and Tadelis (2001) to incorporate the insights of the property rights approach.

Bajari and Tadelis (2001) observe that one can view the degree of contract completeness as a relationship specific investment. They show that the choice between fixed price contracts and cost plus contracts entails a trade-off between the *ex ante* cost of planning in the case of fixed price contracts versus the *ex post* benefit of lower renegotiation costs in the case of cost plus contracts. A key hypothesis is that the division of bargaining power at the time of renegotiation is assumed fixed. As consequence, the contracts they study do not achieve the first best.

Beginning with Hart and Moore (1988), a number of papers have made the point that one of the roles that a contract plays is to structure the renegotiation game.[4] Chung (1991) and Aghion, Dewatripont, and Rey (1994) show that, when parties have available the legal instrument of *specific performance* and can allocate bargaining power to either the buyer or the seller, one can write a contract that can simultaneously achieve efficient investment, risk bearing and matching. Specific performance is the legal remedy that most closely approximates the economist's notion of a complete contract. If one agrees to trade a good with quality q at price p and if both variables are publicly observable, then it is assumed that the contract as written will be enforced. The difficulty, as Holmes observes in the quotation above, is that the law does not enforce contracts in this manner.[5] Rather, the courts make an estimation of damages and require the breaching party to make payment to the harmed party. In other words, even if a contract is complete in the economist's sense, in practice one cannot rely upon the courts to enforce the contract as written. This point is illustrated with a simple example in the next section.

Given this, the next question is exactly how do parties write an enforceable contract that ensures delivery of the promised project? We address this question in section 2. There, we review many of the features of the standard form contracts published by the American Institute of Architects (AIA). The AIA began publishing these forms in 1914, and they are widely used to regulate all aspects of the construction process. These contracts have evolved over time in response to both industry feedback and litigation in court. Thus,

[4] See Chung (1991), Aghion, Dewatripont, and Rey (1994), MacLeod and Malcomson (1993) and Edlin and Reichelstein (1996).

[5] Specific performance is enforced in cases involving unique goods such as real estate or art. In the United States for goods easily available in the market, monetary damages equal to the value of the goods promised are used.

these contracts are an example of how complex trade is enforced in practice.

Secondly, we make the case that these contracts can be viewed as an *efficient* solution to the problem of contract enforcement given the available legal instruments. It is impossible to prove this, and moreover there is continual innovation in contract terms. However, western society has thousands of years of experience with complex construction projects. In the 1st century B.C., Vitruvius, Morgan, and Warren (1914), the great Roman architect, recommended in book 1, chapter 1 of his "Ten Books on Architecture":

> And other things of this sort should be known to architects, so that, before they begin upon buildings, they may be careful not to leave disputed points for the householders to settle after the works are finished, and so that in drawing up contracts the interests of both employer and contractor may be wisely safe-guarded. For if a contract is skillfully drawn, each may obtain a release from the other without disadvantage.

Accordingly, we begin with the hypothesis that construction contracts are efficient, and introduce in section 3 a model that can explain the salient features of form construction contracts. In particular, the complex structure of these contracts can be explained by the need to address a number of distinct transactions costs. These include incentives for the builder to make an efficient investment into design, incentives to the contractor to ensure that he minimizes cost given the design, and, finally, incentives to the builder to truthfully reveal necessary changes to the design *ex post.*

We show that the returns from design at the *ex ante* stage are non-concave, and hence, when the marginal benefit from design is sufficiently small, it is efficient to engage in no design *ex ante.* In that case, the optimal construction contract is cost plus. Under this contract, the builder has full residual control rights, and compensation to the contractor is equal to his out of pocket expenses.

When the marginal benefit from design is greater than the marginal cost, the optimal contract corresponds to the salient features of a fixed price contract. After making some investment in design, the builder asks contractors to bid for the right to the project. The builder selects the low bid, then the contractor makes relationship specific investments into the project. A crucial ingredient of fixed price contracts is an explicit division of control rights into three sets of tasks. Tasks that involve the method by which the building is executed are under the control of the contractor. This provides the appropriate incentives under a fixed price contract for the contractor to select the low cost method of construction.

In contrast, the builder has the right to request minor modifications to the *design* after the fact at no cost. In other words, even when the contract is *complete* in the sense that, say, the location of a wall is clearly specified, if adjusting its location by a few inches has a minor effect on costs, then the contractor is *obliged* to make the adjustment. If the adjustment has a large impact upon the builders preferences (for example, without the adjustment, the builder would not be able to move a piano into the building, dramatically reducing her gains from trade), then existing incomplete contract models, such as in Aghion, Dewatripont, and Rey (1994) and in Bajari and Tadelis (2001), imply that the builder and the contractor would share in the total gains from the modification, even if the cost to the contractor is trivial.

Hence, in the face of contractual incompleteness, the standard fixed price construction contract explicitly avoids the use of a specific performance clause and allocates control rights to either the contractor or the builder, depending upon whose preferences are most appropriate for directing the activities *ex post.* In many cases, the modifications requested by the builder may add significant additional costs to the project. In these cases, the standard construction contract still allocates full control rights to the builder, and hence if the contractor does not execute the requested change he will be in breach of contract. However, the builder now has an obligation to compensate the contractor for the additional costs, while the contractor has an obligation to have good records and to be able to provide evidence of the additional costs.

This behavior fits nicely with the results from mechanism design theory, and it illustrates the importance of understanding the endogenous creation of information systems. We know from Myerson and Satterthwaite (1983) that renegotiation with two sided asymmetric information leads to *ex post* inefficient outcomes. The construction example illustrates that this is a real issue; however, the solution is not to design the best mechanism conditional upon the asymmetric information, nor necessarily to leave the contract incomplete, as suggested by Spier (1992). Rather, given that it is less expensive to measure costs than to measure a builder's subjective evaluation of a design modification, the optimal contract allocates control rights to the builder and places a reporting obligation upon the contractor.

This solution also economizes upon writing costs. In the context of an insurance contract, Townsend (1979) and Dye (1985) show that writing costs imply more pooling that is optimal in the absence of writing costs. Anderlini and Felli (1994) and Battigalli and Maggi (2002) extend this results to provide theories of incomplete contracts based upon the cost of adding clauses to a contract. Construction contracts provides a concrete illustration of how in the case of procurement these writing costs can be lowered via the allocation of control rights.

In Section 4.3, we present the main result of the paper, demonstrating that the standard fixed price contract as used in the United States corresponds to an optimal contract that efficiently regulates the relationship *ex ante* and *ex post.* In the final section of the paper, we apply this result to the theory of law of contract damages.

Contracts are legally enforceable because the courts require a party who has breached a contract to pay damages to the harmed party. It is often the case that the contract does not specify the size of these damages, and hence the court needs some principles to guide this choice. Beginning with Goetz and Scott (1980), the law and economics approach proposes that the courts use the damage rule that the parties themselves would have chosen if they had the foresight to include liquidation damages for the event leading to the breach. We show that our model can provide a unified framework that incorporates several of the standard doctrines of contract law - limitation of liability to foreseeable losses, expectation damages, and excuse from performance in the case of mistake or impossibility.

1.1 Specific Performance - An Example

A contract is incomplete if terms are not supplied for some events or if the terms supplied are inefficient or impractical. In either case, parties have incentives to renegotiate the contract. The outcome of renegotiation depends upon how the contract determines the default whenever unanticipated events occur. In these cases, the outcome specified in the contract document, together with the courts, determines the default in the absence of renegotiation. In this section, we consider a simple example that illustrates some of the problems with trying to define the default appropriately and with the presumption that specific performance is an efficient remedy. Consider the problem of securing a contract to paint one's house. Suppose that one feels that bright pink is a nice color, then one asks a number of contractors to submit bids. The low bid turns out to be $5,000.

Of this amount, suppose that $1,000 is the cost of the paint, $3,000 is the cost of labor, and $1,000 is the contractor's profit. Let us further suppose that one is willing to pay up to $8,000 to have the house painted pink. Now, suppose that, after signing the contract and after the contractor has purchased the paint, one learns that there is strict style code for the neighborhood that restricts all colors to a light grey (as in Nantucket's strict building codes). Further suppose that the homeowner would have to pay a $10,000 fine if this rule were contravened. Upon learning this, one informs the contractor that one no longer wishes bright pink but would like to have a light grey color which has a valuation of at most $7,000. Suppose that the paint contractor, in accepting this job, has turned down other jobs for the same period, and hence his alternative is to have zero profits.

The contract we have specified here is, to use the terminology of Ayres and Gertner (1989), obligationally complete, and hence it is complete in the economic sense of specifying the actions of the parties in every state of nature. However, the contract is not always efficient *ex post.* Following Hart and Moore (1988), suppose that the parties efficiently renegotiate with equal bargaining power from a default defined by the contract. The question then is what are the default payoffs that the courts would enforce? There are at least 3 cases to consider:

1. Specific performance - this is the rule used in many economic models. Namely, the contract is enforced as written, and hence in the absence of renegotiation the payoffs are:

$$\begin{aligned} U_P^0 &= \$8,000 - \$5,000 - \$10,000 \\ &= -\$7,000 \\ U_A^0 &= \$5,000 - \$1,000 - \$3,000 \\ &= \$1,000. \end{aligned}$$

   Under this contract, the owner (Principal) would have a net utility after renegotiation of $U_P = -\$1,500$, while the contractor (Agent) has a gain of $U_A = \$3,500$.

2. Expectations damages - this is the standard common law rule. It requires that the breaching party fully compensate the harmed party for the damages that the harmed party suffered. In this case, the contractor would expect a profit of $1,000 plus the cost of the paint, and hence the default would be to not have the house painted, with default payoffs:

$$\begin{aligned} U_P^0 &= -\$1,000 - \$2,000 \\ &= -\$3,000 \\ U_A^0 &= \$1,000. \end{aligned}$$

   The parties would then renegotiate to have the house painted, and owner would have a net utility after renegotiation of $U_P = \$500$, while the contractor has a gain of $U_A = \$1,500$.

3. Under US Common law rule and under most standard form construction contracts, such as AIA A201, this change would not be considered a breach of contract but, rather, a modification of the terms. In that case, the law explicitly does not allow the contractor to enrich himself at the expense of the owner.[6] Rather, the contractor is obliged to paint the house with the new color specifications, while the owner is required to compensate the contractor for any costs resulting from the modification. In this case, payoffs to the owner (Principal) and contractor (Agent) are:

$$\begin{aligned} U_P &= \$7,000 - \$1,000 - 5,000 \\ &= \$1,000 \\ U_A^0 &= \$1,000. \end{aligned}$$

   Under this interpretation, the contractor is neither harmed nor does he benefit from the owner's change in plans. At the same time, the owner still faces the full cost of the need to change the contract, but she is not held up by the contractor.

Beginning with Shavell (1984) and with Rogerson (1984), the economics literature on legal default rules compares the rules of specific performance: the first case, expectations damages and the second case but not the third case. One might argue that the third case is an example of reliance based damages - the buyer compensates the seller for out of pocket losses, in this case the cost of the paint. This would not be the correct legal interpretation because the law would not view the change in paint color as a breach of contract. Rather, after the owner has informed the contractor of the paint change, the contractor has an *obligation* to paint the house light grey. Breach would occur either if the contractor refused to paint the house or if the owner refused to compensate the contractor adequately for the change in specifications.

Economic models of incomplete contract typically assume that, when an unforeseen event occurs, the parties have to renegotiate to a new contract. This example illustrates that this is not necessarily the case. In some situations, one party has the right to make a unilateral modification of the terms and still have a binding agreement. This is very much consistent with the property rights approach to the theory of the firm. The difference is that, in the case of an asset, the owner has residual control rights until the asset is sold. In this case, the builder or owner has control rights over the contractor until the completion of the project. In this way, a construction contract can be viewed as an intermediate organizational form between full integration of the contractor and the builder and a simple sales contract executed at a single point in time.

2 The American Institute of Architects (AIA) Form Construction Contracts

This section reviews some of the salient economic features of the form construction contracts published by the American Institute of Architects (AIA). These contracts are the most widely used in the industry, and they

[6] See section 4.D of Farnsworth (1990). As it turns out a number of doctrines will lead to the same outcome. We are grateful to Victor Goldberg for pointing this out.

cover all aspects of the construction process. There are almost 100 different forms that are copyrighted and available at a modest price, varying from \$3.50 to \$18 (and at a discount for AIA members).[7] In this paper, we are concerned with the so-called A-series, which consists of 25 forms that govern various aspects of the owner-contractor relationship. The other series deals with the owner-architect relationship, with equipment suppliers, and with various forms of construction management. The A-series contracts are used after the owner has obtained plans for a project from an architect. The main components to an agreement between the owner and the contractor consist of the set of forms illustrated in table 1.[8]

We have just listed the two main forms of compensation, a fixed-price contract (form A101^{TM}-1997) and a cost-plus contract (A114^{TM}-2001). Another popular form is the cost-plus with a guaranteed maximum, or GMAX, contract. We discussed with a real estate attorney the salient features of the GMAX contract, and he told us that one normally reaches the guaranteed maximum price.[9] Hence, from an economic point of view, the contract is equivalent to a fixed-price contract. Secondly, he said that it is popular because it ensures that one has in place an accounting system that measures costs, and hence it is consistent with our assumption that costs are measurable. As stated in the table, all of the compensation contracts are designed to be used with A201^{TM}-1997, which provides the mechanism that governs renegotiation of the contract.

The AIA contracts generally cover all kinds of projects including public and private, residential and commercial. The contracts vary across type of projects. The AIA documents are used for all kinds of projects. Contracts are listed under following groups: *conventional family*, *small projects family, construction manager-adviser family, construction manager-contractor family, interior design family*, and *design/build family.* For instance, the most general class of documents is listed under the group *conventional family* contracts. The contracts provided under this group are meant to be used for small to large projects, specifically where the project can be divided into separate tasks. The contracts available under this general group, include those where the compensation mechanism is cost plus (A111^{TM} -1997 and A114^{TM} -2001) and those where the payment scheme is fixed price (A107^{TM} -1997). *Small projects family* (A105^{TM} -1993) contracts are for small straightforward, short duration projects where the payment scheme is fixed price. *Interior design family* group of contracts (A175^{TM} -2003) are also fixed price contracts and are typically meant to be used for small to large tenant projects in cases of interior design and construction. *Construction manager-adviser family, construction manager-contractor family, and design/build family* depend on the organization of the project. In case manager adviser is used to provide expertise in the project, documents A101Cma^{TM} -1997 and A201Cma^{TM} -1997 are used. These detail the organizational responsibility of the various agents involved and the payment scheme. They are used for large and small, private and public projects. For projects where the contractor is also the main manager, *construction manager-contractor family* of contracts are used (A121Cmc^{TM} -2003 and A131Cmc^{TM} -2003). These are used for private projects, both small and large. A121Cmc^{TM} -2003 is a GMAX contract and A131Cmc^{TM} -2003 is a cost plus contract. These documents, along with A201^{TM} -1997 specify the rules of and the responsibilities for the project. Finally,

[7] Sweet (2000) has copies of the 1997 series of the form construction contracts in the appendix. See also www.aia.org/documents on the AIA website.

[8] See the AIA website for more information: http://www.aia.org/documents/about/synopses/series/.

[9] Kenneth Williams of Cox, Castle and Nicholson LLP was kind enough to meet with us and provide us with some insights into the construction industry.

design/build family contracts A191DB^{TM} -1996 are used if the designer builds the contract as well.

Before hiring a contractor, the owner normally hires an architect using the form contract 1997-B141. This contract is interesting in its own right, but it is not the focus of the present analysis. The salient point is that the architect is required to produce a set of plans, which are then used as the basis for bid formation by the prospective contractors. The quality and the completeness of these plans vary from project to project. As we shall see, this quality will have a bearing upon the total cost of the project. However, regardless of the quality of the plans, it is well understood that they are *necessarily* incomplete. Moreover, once construction has begun and both parties have made significant relationship-specific investments, there is always a risk of holdup when a contract is renegotiated in the face of an unforeseen contingency.[10] Here, we review the various techniques used in these contracts to deal with the problems created by holdup by and unforeseen contingencies.

2.1 Creating Commitment

Contractors are typically selected by some form of sealed-bid auction. This normally means that the owner chooses the lowest bid; although, she has the legal right to choose any bidder that she wishes.[11] For example, one might not wish to choose the lowest bid if quality is an issue; although, this can be addressed by requiring bidders to prequalify, a normal practice for large projects.

Once a contract has been chosen, the contractor has an incentive to use the fact that he is preferred over the other contractors to attempt to renegotiate. This problem becomes even more serious as the project proceeds, since both parties have made significant relationship-specific investments. The question, then, is how do these contracts deal with the potential for *ex post opportunism?*[12] For example, the owner may wish to have the contractor carry out some minor changes to the project, and, in response, the contractor may threaten to hold up the project in order to extract a high price for these changes. Construction contracts have a number of features to explicitly address this possibility.

In order to deal with the threat of nonperformance, contractors are required to post bonds, as detailed in forms A701 and A312. Construction projects are so complex that they require continual monitoring by the owner during the execution of the project. Hence, courts cannot enforce performance per se, rather, they enforce transfers as a function of events that occur in the execution of the contract. The bonds provided under form A312 address two issues. The payment bond ensures that subcontractors are paid in the event that the contractor does not complete payment. This is necessary for the owner since subcontractors can impose a mechanic's lien against the building in the event of nonpayment by the contractor. These liens in turn generate liability against the owner, which would be covered by the payment bond.

The second part of the bonding contract consists of a performance bond. This bond ensures that, should the contractor not complete the job, there are sufficient funds available to find another contractor who would

[10]The combination of incomplete contracts and holdup is central to the theory of vertical integration, as studied by Williamson (1975), by Klein, Crawford, and Alchian (1978), and by Grossman and Hart (1986). Tirole (1986) has shown that these issues are also relevant for the problem of procurement.

[11]Universal By-Products Inc. v City of Modesto (1974) 43 CA3d 145. The city of Modesto was sued for not granting the contract to the lowest bidder. The court ruled in favor of the city.

[12]See Williamson (1975) section, 2.2.2.

be able to complete the work.[13] Hence, under an AIA contract, the courts would never be asked to enforce performance per se, but, in the event of a dispute, they might be asked to verify that the contractor had indeed ceased work on the project (the contract specifies the time delays involved in determining whether work has stopped), which would then release funds that the owner could use to hire another contractor. In addition, the Principal has the right to confiscate all equipment on site and use it for the completion of the project.[14] Thus, the bond effectively allocates bargaining power to the Principal when the Agent breaches the contract.

Similarly, the contractor is also protected because payments are made as work proceeds as a function of the contractor's costs, and hence the amounts owing to the contractor at any point in time are limited. In this way, the contract is carefully structured so that bargaining power can be reallocated between parties as a function of who is in breach of the contract. The next question regards the design of the contract renegotiation process.

2.2 Principal Authority and Unforeseen Contingencies

The bidding process, combined with the bonding agreement, ensures that, at the beginning of the project, the owner is the residual claimant on the value of the project and that the power of the contractor is limited *ex post.* The main part of a standard construction contract consists of forms A101 and A201 combined with the attached plans and specifications. It is well recognized that the project plans are necessarily incomplete, and hence the contract must have a mechanism to deal with *ex post* modifications. Beginning with Grossman and Hart (1986) and with Tirole (1986), the common assumption in the economics literature on incomplete contracts is to suppose that the bargaining rule is exogenously given in the face of an unforeseen contingency.

Yet one of the key features of construction contracts is that each party's bargaining power depends upon the nature of the unforeseen contingency. Specifically, form construction contracts are carefully designed to allocate bargaining power to either the owner or the contractor as a function of the task at hand. For example, suppose that plans call for white paint, but, after the contract is signed, the owner decides that she prefers blue and that this increases the value of the project to the owner by $5,000. The theory of incomplete contracts predicts that, in this case, the contractor would be able to extract a rent from the owner for this change. This is under the presumption that, since white is written into the contract, the courts would not consider the contractor in violation of the contract should the building be painted white.

The AIA contracts explicitly allow for the owner to make changes without being in breach of the contract. Should the contractor, consistent with the plans, paint the house white against the express wishes of the owner, then the contractor, not the owner, would be in breach of contract. Clause 4.2.8 of form A201 gives the right to the owner or architect to carry out minor changes at no penalty. Hence, even if paint had been purchased and the owner changed the paint color, then she would be liable for, at most, the cost of tinting

[13] The first clause of A312 states: "The contractor and the Surety, jointly and severally, bind themselves, their heir, executors, administrators, successors and assigns to the Owner for the performance of the Construction Contract, which is incorporated herein by reference."

[14] This confiscation is consistent with Oliver Hart's observation that authority also includes control over physical assets. — See Hart (1995) page 58.

the paint. In addition, clauses 4.2.13 and 7.1.1 in form A201 explicitly give power to the Principal, and they provide a mechanism by which changes can be implemented.[15]

For substantial changes outside of the scope of the original contract, the contractor is still required to complete the task at the request of the owner, but he also has the right to recover costs. These changes can be achieved with a change order, which details the additional work and the cost of this work that has been mutually agreed upon between the contractor and the owner. When the owner and the contractor cannot agree upon costs, the owner can still ensure performance by issuing a *change directive*. Under article 7 of form A201, the contractor is required to carry out the work specified in a change directive; otherwise, he is in breach of contract. If the payment for the changes proposed by the owner is in dispute, then the contract requires the parties to first enter mediation. If this fails, then the case is brought before an arbitrator, so a binding judgment can be made. Ultimately, the enforcement of the arbitration judgment falls upon the courts, which, in some circumstances, may overrule the arbitrator's decision.[16]

Litigation can and does arise regarding the cost of work. However, for the most part, disputes are resolved without having to resort to litigation. To reduce any potential conflict regarding costs, fixed-price contracts often include, under article 4.3 of form A101, explicit unit prices for aspects of the work that are uncertain *ex ante*. Hence, even though a contract is ostensibly fixed-price, it can formally include a number of clauses that regulate *ex post* adjustments to price. It is also clear that a contractor is in breach of contract if he attempts to slow the project in order to gain bargaining advantage. To address this problem, article 3.3 of form A101 allows the owner to include liquidated damages for delays in the completion of the project.

In summary, the AIA form construction contracts explicitly give the owner the right to direct the work. For work within the scope of the original contract, the agreed-upon price is expected to cover the costs, while the contractor is obliged to carry out changes that are significant variations upon the original contract and has the right to be reimbursed for the cost of these changes. Explicit in these forms is the assumption that it is possible to put into place accounting systems that track costs. Even though the owner has overall control, she does not control every aspect of the project. In particular, many tasks, involving the manner by which the building is constructed are left under the control of the contractor.

2.3 Contractor Authority and the Correction of Defects

Although construction contracts give overall control of the project to the owner, they are not completely one-sided. If the owner and the contractor were formally part of a single enterprise, then the owner would have control over both the outcome of the project and the way in which the workers on the project were

[15]These clauses are:

- 4.2.13 The Architect's decisions on matters relating to aesthetic effect will be final if consistent with the intent expressed in the Contract Documents.
- 7.1.1 Changes in the Work may be accomplished after the execution of the Contract, and without invalidating the Contract, by Change Order, Construction Change Directive or order for a minor change in the Work, subject to the limitations stated in the Article 7 and elsewhere in the Contract Documents.

[16]See Chapter 30 of Sweet (2000) for an extensive discussion of dispute resolution and of the conditions under which binding arbitration may be overuled.

managed. This is not the case in construction. Section 3 of form A201 outlines the responsibilities of the contractor, with clause 3.3.1 stating that: The Contractor shall be solely responsible for and have control over construction means, methods, techniques and procedures and for coordinating all portions of the Work under the Contract, unless the Contract Documents give other specific instructions concerning these matters.

Thus, the owner does not have the right to directly control the employees of the contractor, and hence the construction relationship is different from a formal employment relationship. The contractor also has the right, under section 5 of form A201, to hire subcontractors subject to the approval of the owner. In particular, the contractor has broad control over how to execute the contract; essentially, he has the right to perform the work in the most efficient way possible. An important source of conflict can arise when the completed work is not of the appropriate standard.

Section 12 of form A201 deals with correcting the work performed by the contractor. If there is a defect, then normally the contractor is expected to correct it at his own cost. In some cases, consistent with the allocation of authority to the contractor over the execution of the project, the owner may elect to accept nonconforming work combined with a reduction in the contract price, as allowed under section 12.3 of form A201. If the owner and the contractor cannot agree upon the price change, then they can have the issue brought before an arbitrator and, in extreme cases, litigated in court. This is discussed in more detail in section 6, below.

Finally, while the owner has the right to terminate the project at will, this is not the case for the contractor. He is expected to complete the project, and he is responsible, via the performance bond, for ensuring that the project can be completed if this is the desire of the owner. Exceptions to this rule can be made in the case when events are beyond the control of the contractor, making completion of the project impractical. However, the precise conditions excusing performance, such as the amounts by which the price is to be adjusted for non-conforming work, are not clearly specified in the contract. In this respect, while the form construction contract is rather comprehensive in its allocation of authority, some uncertainties remain regarding the terms for some events, and issues that a formal model can resolve.

3 The Model

Consider a general contracting problem between a risk-neutral Principal and a risk-neutral Agent for the procurement of a complex good that consists of N tasks, denoted by $t \in T = \{1, ..., N\}$. The set T defines the *scope* of the project, namely the set of tasks that the contractor is responsible to complete under the terms of the original agreement. This formalism allows us to introduce two forms of uncertainty. The first, is how best to execute task t, and the second is the existence of unforeseen tasks, T^U, that might be added after the contract has been signed. While the first results in a problem of providing *ex ante* incentives and then deciding the optimal task *ex post*, the latter problem is due to the extra work which may arise later which the contract does not specify. The agent bids and agrees on the price on the assumption that, for the contract price, he will perform only what is covered in the contract T. For example if the Principal is having a house built T, then she may later decide to add another room T^U to the house. If extra work T^U is added, then the agent and the Principal reach an agreement on the price of the extra work.

Without loss of generality, we can suppose that each task can be completed in one of two ways, denoted by $q^t \in \{-1, 1\}$.[17] To keep matters as simple as possible, it is assumed that the value of a task is additively separable from the other tasks. In other words, the total benefit and cost of the project is the sum of the benefits and costs from each task. Complementarity between tasks is captured by the requirement that all tasks must be completed before one has a finished product.

Consider the design problem for task $t \in T$. Initially, the Principal is not sure how she would like to complete the task, but she must engage in some design before beginning the project. Regardless of the quality of the design, one's preferences over a task can change. Let d^t be the amount of money spent in design for task t, and let z^t be the preferred choice for task t. The probability that $z^t = 1$ is the most preferred way to carry out the task is assumed to be $p_u(d^t)$. Without loss of generality, tasks can be normalized so that $z^t = 1$ is the *ex ante,* the preferred method, and hence an increase in planning increases the probability that $z^t = 1$. When there is no planning, the probability of either method being preferred is 1/2.

A key hypothesis of the model is that planning is never perfect; namely, there is always a positive probability that either task may be most preferred. In addition, it is assumed that this information is private, and hence a change in preferences cannot be made part of an explicit contract and must be truthfully elicited *ex post* via an appropriately designed mechanism. The properties of the probability function are summarized in the following condition:

Condition 1 (Uncertain Planning) *The probability function* $p(a) \in [1/2, 1]$ *satisfies the uncertain planning condition if it is twice differentiable,* $p(0) = 1/2$, $p'(a) \geq 0$, $p''(a) < 0$, $p'''(a) < 0$ *for all* $a \geq 0$, *and* $\lim_{a\to\infty} p(a) = 1$. *The degree of* foreseeability *is defined by* $F(a) = 2p(a) - 1$.

These conditions model the idea that increasing investment into planning results in more certainty regarding the desired *ex post* design. However, regardless of the level of investment in design, it is always the case that planning is imperfect. Given a level of planning d, the level of design certainty $F_u(d)$ is a number between 0 and 1. This level plays an important role in the determination of optimal damages. When the level of planning is perfect for task t, then $F_u(d) = 1$, while no planning corresponds to $F_u(d) = 0$. This defines the level of foreseeability in design.

Symmetry in task choices is assumed, and hence the Principal receives monetary payoffs of $u_H^t > u_L^t > 0$ for the most-preferred and the least-preferred choices, respectively.[18] Let $\Delta u^t = u_H^t - u_L^t$ be the difference between the most- and the least-preferred actions for task t. The vector of design decisions made by the Principal is denoted by $D = \{d^t\}_{t\in T}$. It is assumed that this vector is publicly observable. This assumption has two possible interpretations. The first is simply that the Agent, through experience, can predict how often the Principal will change her mind. For example, for residential renovations, if the client does not employ an architect, then the contractor is likely to increase the price because he expects there to be more changes to the plan after work begins. Alternatively, given the design, it is clear to the contractor that there

[17] This statement is nothing more than the statement that one can represent information using binary numbers. For example, suppose that there are four ways to complete a task, A, B, C or D. This can be broken down into a sequence of binary choices. First choose between $\{A, B\}$ and $\{C, D\}$, and then choose an element from each of these subsets.

[18] Notice that symmetry is used to ensure that, if z^t is preferred, then v_H^t is the payoff, and v_L^t is the payoff if $-z_L^t$ is carried out.

are ambiguities to be resolved after the fact, and hence the price must make allowances for these future changes.

After the contract is signed but before actual construction proceeds, the Principal learns her true preferences, and hence it may be optimal to carry out changes to the original design. One could eliminate the need for design by delaying decision making until after this information has been received. However, such a delay makes it impossible for the Agent to plan appropriately, and hence it results in an increase in costs. This is modeled by supposing that, since the Agent knows that $q^t = 1$ is the preferred choice, he can make an investment e^t in cost reducing investments that allow the project to be completed more efficiently. With probability $p_c(e^t)$, the cost of $q^t = 1$ is $c_L^t > 0$, and, with probability $1 - p_c(e^t)$, the cost is $c_H^t > c_L^t$. Symmetry is again assumed, and hence the cost of executing $q^t = -1$ is c_L^t with probability $(1 - p_c(e^t))$ and c_H^t with probability $p_c(e^t)$. Let $\Delta c^t = c_H^t - c_L^t$ be the difference between the high and low-cost actions for task t. This function is also assumed to satisfy the uncertain planning condition, in which case the degree of foreseeability for costs is given by $F_c(e^t) = (2p_c(e^t) - 1)$. Let $x^t \in \{-1, 1\}$ denote the choice that can be realized at low cost and $E = \{e^t\}_{t \in T}$ denote the vector of investments. The level of *planning* for the project is denoted by the vector $\Pi = \{D, E\}$. The relationship between these investments and outcomes for a single task is illustrated in figure 1.

3.1 Information

It is assumed that the *ex ante* investments, E, by the Agent are unobserved but that the *ex post* costs, c^t, are observable. This assumption is consistent with the standard hypothesis in many regulatory models (see, for example, Laffont and Tirole (1986)) that *ex post* costs are observable since firms must have for taxation purposes methods to measure out-of-pocket costs. However, the effort that they exert to lower these costs is difficult, if not impossible, to measure.

The reverse is assumed to be the case for the Principal. When putting the project out for a bid, potential Agents rely upon the design for making their bids. At the time that they bid, they understand that there will certainly be some changes *ex post.* The likelihood that such changes will occur can be estimated given the quality of the original design. In the extreme case of, say, a residential renovation project the Agent may have only a verbal description of the work. In that case, the Agent knows from experience that there may be a large number of changes after the fact that will affect the total costs; this is, in turn, reflected in the bid price.

What Agents do not know is the exact valuation that the Principal places upon different tasks. For some tasks, such as those relating to the aesthetic features of the project, the Principal is likely to have strong preferences regarding how the task is to be completed. In other cases, such as the exact locations of pipes behind the walls, the Principal's preferences are not likely to be that important (assuming that the pipes do not interfere with windows nor with other design elements). In these cases, the Principal would be more concerned with finding low-cost solutions.

This is captured in our model with the hypothesis that tasks have been defined so that they can be carried out in only one of two ways. This implies that the optimal choice depends *either* upon the costs *or* upon the benefits. We call these *Agent-biased* and *Principal-biased* tasks respectively, and they are formally defined as follows:

Case	**Parameter Restriction**	*Ex Post* Optimal Decision
Principal Biased	$\Delta u^t > \Delta c^t$	$q^t = z^t$
Agent Biased	$\Delta c_L^t > \Delta u^t$	$q^t = x^t$

Table 1: Agent versus Principal-Biased Preferences

It is assumed that one can anticipate which tasks should be under the Principal's or the Agent's control (without loss of generality, we assume that the inequalities in Table 1 are strict). The set of Principal-biased tasks is denoted by the set T^P, while the set of *Agent-Biased* tasks denoted T^A, and hence the set of all tasks known *ex ante* is given by $T = T^P \cup T^A$. In practice, one cannot make such a sharp distinction. However, our goal is to understand the *idealized* problem that the AIA form construction contract solves. Thus, we can view this distinction as one in which Principal-biased tasks are ones for which it is most likely that the Principal's preferences are dominant and vice versa for Agent-biased tasks. This is consistent with the structures of the AIA contracts that allocate authority to the Agent over decisions regarding the way in which a building is constructed, which, in principle, should have little impact on the final desirability of the building. Also, we believe that this characterization is justified, since a reading of case law (Jacob & Youngs Inc. v. George E. Kent, 230 N.Y. 239 (1921)) suggests that certain rulings can be explained by the above characterization.

Consistent with this, it is assumed that the exact value of Δu^t for Principal-biased tasks is not known. More formally:

Condition 2 (Agent Beliefs) *1. For Principal-biased tasks, an Agent's beliefs over Δu^t are given by distribution function $g^t(x)$ that is continuous for $x \geq 0$ and $g^t(x) \geq 0$ whenever $x \in (\Delta c^t, m^t)$ and by zero otherwise, where $m^t > \Delta c^t$ is a constant.*

2. For Agent-biased tasks, Δu^t is known with certainty.

This assumption captures the idea that, for tasks with high valuation to the Principal, even if the Agent knows whether a task is Agent- or Principal-biased, there remains some uncertainty regarding the Principal's valuation of a task.

3.2 Optimal Allocation

Given our symmetry assumptions, the relevant question for the determination of the optimal action Q is whether or not the costs and the benefits are aligned, that is, whether or not the high-value choice can be done at low cost. Let $s^t = 1$ if $z^t = x^t$, and $s^t = 0$ otherwise. Then, when $s^t = 0$, the high-value task is chosen if $t \in T^P$, and the low-value task is chosen if $t \in T^A$. Let $s = \{s^t\}_{t \in T} \in S$ define the state or the set of states, respectively, that are relevant for the determination of the value of the project just before its execution, but after preferences have been revealed. Hence, an efficiently executed project has value:

$$V(s) = \sum_{t \in T} v_L^t + s^t \Delta v^t, \tag{1}$$

where:

$$v_L^t = \begin{cases} u_H^t - c_H^t, & t \in T^P, \\ u_L^t - c_L^t, & t \in T^A. \end{cases}$$

and:

$$\begin{aligned} v_1^t &= \begin{cases} \Delta c^t, & t \in T^P, \\ \Delta u^t, & t \in T^A. \end{cases} \\ &= \min \left\{ \Delta c^t, \Delta u^t \right\}. \end{aligned}$$

Notice that, even though the Principal's preferences are uncertain, since $v_1^t = \Delta c^t$ for $t \in T^P$, this parameter is known with certainty for all $t \in T$.

Let $V_L = \sum_{t \in T} v_L^t$ and $\Delta V = \sum_{t \in T} \Delta v^t$; therefore, the *ex post* value of the project satisfies $(\Delta V + V_L) \geq V(s) \geq V_L$. The term v_L^t is the contribution to overall value from task t in the absence of planning, while v_1^t is the maximum benefit that can arise from planning. Under our assumptions, all states in S occur with positive probability, and hence the events $V(s) = (V_1 + V_0)$ and $V(s) = V_L$ both occur with positive probability. Therefore, it is always efficient to complete the project if $V_L > 0$. The vast majority of construction projects are efficient to complete; therefore, we make the following assumption;

Condition 3 (Efficient to Complete) *It is efficient to complete the project regardless of the quality of planning:* $V_0 > 0$.

It is relatively common for projects to stop at the bidding stage, after the contractors make a bid but before construction begins. This has some implications for the architect's fees and about whether the bidding process is considered fair, but these are not issues that we consider here. Once a project has begun, the presumption is that it should be completed, a presumption that is maintained in this paper. Since costs are observable *ex post,* it is not difficult to extend the results to allow for efficient project termination. However, this would be at the cost of some burdensome notation.

The determination of the efficient level of planning depends upon the effect that planning has on the probability that $s^t = 1$. This is given by:

$$\begin{aligned} \Pr\left(s^t = 1\right) &= \Pr\left(z^t = 1 \text{ and } x^t = 1\right) + \Pr\left(z^t = -1 \text{ and } x^t = -1\right) \\ &= p_c\left(e^t\right) p_u\left(d^t\right) + \left(1 - p_c\left(e^t\right)\right)\left(1 - p_u\left(d^t\right)\right) \\ &\equiv \gamma\left(e^t, d^t\right). \end{aligned}$$

Since $\gamma(0, e^t) = \gamma(d^t, 0) = 1/2$, this implies that, if the Principal does not invest in design, then it is never efficient for the Agent to invest in cost reduction and vice versa. More generally, design and cost reduction are complementary, which, as Milgrom and Roberts (1990) show, has interesting implications for the optimal organization of production. Given that it is always efficient to complete the project, the optimal level of planning can be determined for each task as the solution to:

$$\begin{aligned} \left\{d^t, e^t\right\} &\in \arg\max_{d^t, e^t \geq 0} v^t\left(d^t, e^t\right) \\ &= \arg\max_{d^t, e^t \geq 0} v_0^t + \gamma\left(d^t, e^t\right) v_1^t - d^t - e^t. \end{aligned}$$

A solution to this problem always exists because the optimal investment level can be bounded. Observe that the problem is convex since $\partial v^t(0,0)/\partial d^t = \partial v^t(0,0)/\partial e^t = -1 < 0$; therefore, for small v_1^t, it may be optimal to have no planning. When some planning is optimal, the amount of planning is an increasing function of v_1^t, due to the complementarity between design and cost reduction.

Proposition 1 *Given* $v_1^t = \min\{\Delta c^t, \Delta u^t\}$ *and assuming that completion is always efficient (*$V_0 > 0$*), there is a minimal efficiency level* $\Delta > 0$, *such that the optimal amount of design and cost reducing investment into task* $t \in T$ *is* 0 *if* $v_1^t \leq \Delta$. *If* $v_1^t \geq \Delta$, *then there is a unique solution given by* $\{d^{t*}, e^{t*}\} > \{0,0\}$, *the largest solution to:*

$$F_u'\left(d^{t*}\right) = \frac{2}{F_c\left(e^{t*}\right)v_1^t}. \tag{2}$$

$$F_c'\left(e^{t*}\right) = \frac{2}{F_u\left(d^{t*}\right)v_1^t} \tag{3}$$

Moreover, the amount of planning is increasing with v_1^t.

The proof of this and of the subsequent proposition are contained in the appendix. The solution is illustrated diagrammatically in figure 2, found at the end of this report. Notice that there are typically two solutions to the first-order conditions, with the smaller solution corresponding to a local minimum. This illustrates that the optimization problem is convex, and hence, when the benefit v_1^t is small, it is efficient to have no design or cost reduction ($d^t = e^t = 0$). For $v_1^t > \Delta$, the efficient investment, $\{d^{t*}, e^{t*}\}$ is strictly positive and increasing in v_1^t. The net social surplus as a function of different values of v_1^t when the effect of investment is the symmetric ($F_u(a) = F_c(a)$ for all $a \geq 0$) is illustrated in figure 3, found at the end of this report. As one can see, the social return is locally convex for small investment levels.

The level of planning depends only upon v_1^t, but this value itself depends upon whether a task is Principal- or Agent-biased. In cases of Principal-biased tasks, $v_1^t = \Delta c^t$; therefore, the Principal has an incentive to increase design because of the impact that it will have on costs. Hence, the incentive to invest in design arises from the complementarity between design and cost reduction. Conversely, for agent-biased tasks $v_1^t = \Delta u^t$; thus, planning increases with the *value* of the project to the Principal. Hence, in order for the Agent to invest, his income from the project must rise as a function of his investment.

In either case, the optimum illustrates the complementarity that exists between design and costs. Good design results in lower costs. The next section shows that the basic AIA form construction contract provides the appropriate incentives for efficient design and for cost reduction.

4 The Optimal Contract

The purpose of this section is to explore three contract forms that help us to understand the unique structure of the AIA standard construction forms. First, we consider cost plus contracts, and we show that they are optimal only when the return to design is sufficiently low. Next, we look at fixed-price contracts when the Principal and the Agent have symmetric information *ex post* regarding the gains from renegotiation. In this case, it is efficient to allocate all of the *ex post* bargaining power to the Agent. Hence, in order to explain the structure of the AIA form construction, one must suppose that there are transaction costs associated with this outcome. These arise naturally from the hypothesis that the Principal's preferences are uncertain. The contract that implements the efficient allocation in that case has many of the features of the AIA form construction contract. It also implies a damage rule consistent with several of the common-law remedies for breach of contract.

The sequence of decisions for contract formation and performance is illustrated in figure 4, found at the end of this report. The Principal first invests in design, then she selects the Agent. It is assumed that the level of investment at the time that an Agent is chosen is observable by the Agent. The selected Agent then makes an investment into cost reduction. The Principal then realizes her true preferences, and actual costs are realized. The project is then built with changes, as detailed by the procedures in the contract, and followed by payments.

4.1 Cost-Plus Contracts

A cost-plus contract is one in which the Principal pays for all of the Agent's costs. In this case, the Principal can exercise control over all aspects of the project because the Agent is reimbursed for the consequences of these decisions; therefore, he has an incentive to perform as instructed. Formally, the procedure is described by the following sequence of actions:

Cost-Plus Contract :

1. Several agents bid a price P plus costs for a project described by design D.
2. The Principal selects the lowest bid.
3. The Agent reports cost information X to the Principal, who learns her true preferences Z and asks Agent to execute project Q.
4. Project is built; the agent is paid a fixed fee plus costs: $P+ C(Q,X)$.

Under a cost-plus project, the Agent is fully reimbursed for costs, and hence there is no gain from investing in cost reduction. Given the complementarity between design and investment, this implies that the Principal makes no investment. This is optimal when the gains from investment are sufficiently small. Thus we have:

Proposition 2 *Under a cost-plus contract* $d^t = e^t = 0$ *for all* $t \in T$, $P =$ *market profit rate. This contract results in the first best if and only if* $v_1^t \leq \Delta$ *for all* $t \in T$.

This result makes the point that, when there are no incentives for cost reduction, there are no incentives for *ex ante* design. This suggests that, for tasks satisfying $v_1^t < \Delta$, there is no loss in using a cost-plus contract. Moreover, suppose that, after the project begins, one learns that there are additional tasks, denoted by T^U and needed in order to complete the project. Then, regardless of the compensation for the other tasks, it is efficient to use a cost-plus contract for the completion of these tasks, a requirement that is a standard part of all construction contracts.

4.2 Fixed-Price Contracts with Renegotiation

A cost-plus contract ensures that the terms of trade are efficient *ex post*, since it does not provide any incentives for the Agent to reduce costs. The standard solution to this problem is to use a fixed-price contract that ensures that the Agent receives the full reward from any cost reductions.

However, even when trade is efficient, if the Agent has a large cost overrun, then he may still choose to default rather than to perform. If the potential for the cost overrun is unforeseen at the time that the contract is written, then the parties must renegotiate in the face of these developments. In this section, we follow the approaches of Tirole (1986), of Hart and Moore (1988), and, more recently, of Bajari and Tadelis (2001), and we suppose that the renegotiation game is fixed with the original contract acting as a threat point in the bargaining game.

These papers make different assumptions regarding information and the timing of investments. Tirole (1986) supposes that investment by both parties occurs after the contract is signed, followed by bargaining with two-sided asymmetric information. Tirole's proposition 1 shows that this leads to under-investment when investment is not observable. Since there is two-sided asymmetric information, this general result does not depend upon the allocation of bargaining power.

Hart and Moore (1988) also suppose that investment takes place after the contract is signed and that the contract cannot be contingent upon information that is revealed *ex post.* The hypothesis of symmetric information *ex post* implies that contract price and quantity are renegotiated to an efficient outcome with the original contract terms acting as a threat point, and it corresponds to the case that we consider here. With two-sided investment, they show that it is not possible to achieve an efficient allocation. The interesting point made by Bajari and Tadelis (2001) is that it may be more appropriate to suppose that the investment made by the Principal is the level of design that is carried out *ex ante* before the contract is signed. We consider the implications of this for the Hart and Moore (1988) analysis in the context of our model. Formally, a fixed-price contract with renegotiation is defined as follows:

Fixed-Price Contract with Renegotiation :

1. Agents in a competitive market bid a price P for a project described by $\{D, T\}$, where $D = \{d^t\}_{t \in T}$ is the quality of the design for the project, $(p_u(d^t)$ is the probability, and $q^t = 1$ is the preferred action.
2. The lowest price bidder is chosen, and he then makes a cost reducing investment $E = \{e^t\}_{t \in T}$.
3. The Principal and the Agent learn their true preferences Z and X.
4. The Principal and the Agent renegotiate the contract according to the following rule:
   (a) For each task, with probability λ, the Agent makes a take-it-or-leave-it offer to the Principal to have $q^t = -1$ implemented for a change in price δp^t. Similarly, with probability $(1 - \lambda)$, the Principal asks the Agent to carry out $q^t = -1$ for a price change of δp^t.
   (b) For unforeseen tasks in T^U, a similar procedure is used, but the difference is that the default is the task not carried out, and there is no price change.
5. The Project is built with the renegotiated specifications Q, and the Agent is paid $P + \sum_{t \in T \cup T^U} \delta p^t$.

Since preferences and costs are common knowledge, renegotiation always implies an efficient outcome *ex post.* However, in contrast to the results of Hart and Moore (1988), the fact that the Principal's investment occurs before the contract is signed implies that one can implement the first best if the bargaining power of the Agent is a choice variable and if information is symmetric *ex post:*

Proposition 3 *Suppose that the Agent knows Δu^t for every task t. Then, if the Principal has all of the bargaining power at the contract formation stage and if the Agent has all of the bargaining power* ex post, *then the fixed-price contract with renegotiation implements the efficient solution. Conversely, if the Principal has some bargaining power* ex post, *then the Agent overinvests in cost reduction, and the Principal overinvests in design relative to the first best.*

The efficiency of the design is a consequence of the competitive bidding procedure. Much of the literature on procurement has emphasized the importance of competitive bidding to reveal the low-cost supplier (see, for example, McAfee and McMillan (1987)). This result highlights the idea that competitive bidding can also be viewed as a mechanism for allocating the *ex ante* bargaining power to the Principal. In order to also provide the Agent with appropriate incentives, it is necessary to allocate to him all of the *ex post* bargaining power. If power is divided *ex post,* then one obtains the standard hold-up result of inefficient investment.

This result illustrates a point first made by Aghion, Dewatripont, and Rey (1994); namely, one can achieve an efficient outcome by an appropriate design of the renegotiation process. Their model is based upon the idea that one person is assigned all of the bargaining power, while the other party is provided with correct incentives via an appropriately defined default. In this case, it is the sequential reallocation of bargaining power that achieves the first best. This mechanism is similar to others that have been developed in the literature, including option contracts as in Demski and Sappington (1991), Nöldeke and Schmidt (1995), and Edlin and Hermalin (2000). Aghion and Tirole (1994) make a similar point in the context of R&D contracts where design can be viewed as an innovative activity that eventually results in a marketable product. Note that the extras, T^U, will be executed according to the cost reimbursement. This is due to the fact that for tasks in T^U there is no gain from providing effort incentives.

However, these contracts cannot explain several of the important features of the AIA form construction contract, including the allocation of authority to the Principal *ex post* and the right of the Principal to make minor changes at no cost. To explain these features, we need to introduce an additional transactions cost, such as uncertainty regarding the Principal's preferences (as in condition 2). In that case, the fixed-price contract with renegotiation cannot implement the efficient allocation.

Proposition 4 *Under condition 2, the fixed-price contract with renegotiation does not implement the optimal allocation, regardless of the* ex post *bargaining power of the Agent.*

The reason for this is straightforward. In order to ensure efficient renegotiation when there is private information on the Principal's side, one must allocate all *ex post* bargaining power to the Principal. However, from the previous proposition, this reduces the incentives for the Agent to make cost reducing investments, and hence one obtains an inefficient allocation.

4.3 Fixed-Price Contracts with Remedies

Under the AIA form construction contract, the Principal has the right to make changes to tasks that lie within the scope of the project at no additional cost. This has two effects. Given the design, the Agent can anticipate this behavior, and thus increase his bid for projects with poor design, which in turn provides incentives to the Principal to invest in design. When design is of high quality, the Agent does not expect a large number of changes *ex post,* and he correspondingly makes greater relationship-specific investments in cost reduction. Secondly, since the Principal now receives the residual returns from any changes, she has the incentive to reveal her true *ex post* preferences.

A request for major changes can be interpreted as adding new, unforeseen tasks to the project, denoted by T^U in the previous section. Since they are unforeseen, the efficient level of design and of cost reducing investment is zero, and hence by proposition 2 it is efficient to govern the compensation of these tasks with a cost-plus contract.

The case of Agent-biased tasks is more difficult. In this case, the Agent should have authority to carry out the task as he wishes. However, as we show above, efficiency cannot be achieved with a cost-plus contract when $e^t > 0$. The AIA construction form contract solves this problem with a clause that requires the Agent to either complete the task as requested or to lower the price. For Agent-biased tasks, a price reduction is the efficient solution, or, equivalently, the Agent is asked to pay damages to the Principal for not executing a task as directed. This can be formalized as follows:

Fixed-Price Contract with Remedies :

1. Agents in a competitive market bid a price P for a project described by $\left\{D, T^P, T^A, L\right\}$, where:
   (a) $D = \{d^t\}_{t \in T}$ is the quality of the design for the project.
   (b) T^P describes the scope of the changes that the Principal can impose without cost.
   (c) T^A are the tasks where the contract is literally interpreted. Damages for changes in T^A are given by $L = \{l^t\}_{t \in T^A}$.
2. The lowest-price bidder is chosen, and he then makes a cost reducing investment $E = \{e^t\}_{t \in T}$.
3. The Principal learns her true preferences Z', and she instructs the agent to carry out $z^{t\prime}$ for tasks $t \in T^P$. Damages are awarded for tasks in $t \in T^A$ where there is a dispute. Any additional tasks given by the set T^U are carried out on a cost-plus basis under the direction of the Principal.
4. The Project is built and the agent is paid P less total damages plus the cost of completing any tasks in T^U.

Under the hypothesis that all Agents are identical, the fixed-price contract results in the first-best allocation:[19]

[19] The result can be easily extended to allow for uncertain costs. For example, suppose that the contractors vary in their alternative opportunities, then a second price auction will implement the first best. The exact terms of the bids depend upon which elements are not observed, so the rules of the contract may vary as a function of context. The essential feature of any efficient mechanism is that the Principal is the residual recipient of any rents from the project that arise from good design.

Proposition 5 *A fixed-price contract with remedies results in the first-best allocation, with damages set to* $l_s^t = F_u(d^{t*})\Delta u^t$ *whenever* $q^t = -1$. *Moreover, the equilibrium price is given by:*

$$\begin{aligned} P &= \textit{market profit rate} \\ &\quad + \textit{expected damage payments} \\ &\quad + \textit{expected cost of anticipated tasks.} \end{aligned}$$

The optimal-damage rule is given by $l_s^t = F_u(d^{t*})\Delta u^t < \Delta c^t$, and hence the Agent will select the low-cost alternative, even when a damage payment is required. In practice, this rule is implemented by the Agent agreeing to a price reduction when performance has deviated from the specification. Such a reduction in price is not only part of the AIA form construction contract, but it is also part of the Uniform Commercial Code for the United States.

Observe that damages are decreasing with the optimal amount of planning and that they include complete delegation of authority either to the Principal or to the Agent as a special case. For example, under the AIA form construction

contract, the Agent can manage the project as he wishes. Since the Principal only cares about the final outcome, tasks corresponding to building procedures would satisfy $\Delta u^t = 0$, and hence there would be no damages.

When no planning is optimal, $d^{t*} = 0$, and the degree of foreseeability is zero ($F_u(d^{t*}) = 0$). Hence, damages in this case are also zero, $l_s^t = 0$, and the Agent is free to select q^t as he wishes. If it is efficient for $d^{t*} = e^{t*} = 0$ for all $t \in T$, then both the fixed-price and the cost-plus contracts are efficient. Under a fixed-price contract, the equilibrium price would be:

$$P = \Pi^0 + \sum_{t \in T^P} \left(c_H^t + c_L^t\right)/2 + \sum_{t \in T^A} c_L^t.$$

However, under this contract, there is a 50 percent probability that the total cost is greater than the price. Hence, the cost-plus contract may be preferred if the Agent is risk-averse and/or if he faces a bankruptcy constraint.[20]

Moreover, even when a pure cost-plus contract is not efficient, the Principal may use a mixture of cost-plus and fixed-price terms to reduce the risk to the Agent. More formally:

Corollary 6 *Let* T^C *be the set of tasks for which it is optimal to have no planning, that is,* $d^{t*} = 0$. *It is optimal to reimburse the Agent for the cost of these tasks and to let the other tasks be covered by the provisions of a fixed-price contract.*

In practice, it is common to include cost-plus terms for some aspects of the work where the amount of work is not known in advance and where the Principal would like to lock in the price per unit. It is surprising, then, that the AIA form construction contract does not provide much guidance regarding how to renegotiate the contract price when quality is deficient. This may be evidence supporting Shavell's point that it may simply be cheaper to let the dispute-resolution system determine the remedy, than to attempt to specify a

[20] See McAfee and McMillan (1986) for an analysis of this case.

potentially complex formula *ex ante.* [21]The point is further explored in the next section, where it is shown that the optimal liability rule is consistent with several of the standard doctrines of contract law.

5 Legal Default Rules

When a contract is well-designed and complete, we should not observe breach in equilibrium. This is because the contract specifies payments for every contingency, including nonperformance. This observation is a starting point for the economic analysis of remedies. Namely, in the event that a contingency not covered by the contract occurs, one can ask what terms the parties would have agreed upon *ex ante* to deal with this contingency. The economic theory of contract remedies then supposes that it is efficient for the courts to enforce this rule (see Posner (2003)). The precise rule that is optimal is sensitive to the problem at hand, and hence the literature has produced many examples illustrating that standard contract remedies may be inefficient.

In cases of incomplete performance, of delays, or of missed payments, the AIA forms are explicit regarding the nature of damages, as we have discussed above. When there are defects in quality or when the contractor disregards the design, the AIA form construction contract simply states that the owner may request a reduction in price if the Agent does not correct a defect. Hence, it is not surprising that this is the most common type of claim to arrive in court. In this section, we discusses a number of the standard remedies and excuses for the common law in the context of our model.

The standard remedy is *expectation damages:* the harmed party is put into the same position as she would have been if there were performance (see Farnsworth (1990), Chapter 12). In the context of our model, the contract is interpreted as requiring $q = 1$, and hence the damage to the Buyer is $(u_P - u_B)$, the difference in the value under performance (u_P) and under breach(u_B). The alternative is *specific performance.* This is the requirement that the project be completed. The courts cannot, in practice, enforce actual performance, except in the cases of transfers of property. The best that they can do is award to the plaintiff an amount that allows her to pay for the completion of the project as she desires. In the context of our model, this is the amount $(c_P - c_B)$. The damage rule that we have derived combines these two measures by taking the minimum of expectations and costs. When the Agent is in breach, this amount is multiplied by the degree of foreseeability of the task. Consider first cases for which the contract terms are foreseeable.

5.1 Expectation Damages versus Specific Performance

Many scholars, beginning with the legal analysis of Schwartz (1979)and including the formal analyses in Rogerson (1984), in Chung (1991), in Aghion, Dewatripont, and Rey (1994), and in Edlin and Reichelstein (1996), have argued that the courts should use specific performance. In the case of construction, it is impossible to force an unwilling Agent to perform; hence, specific performance is achieved by awarding to the Principal the cost of performance that allows her to hire another Agent to complete the work.

In practice, the courts are reluctant to award specific performance when the cost of performance is believed to be much larger than the value of performance. Sweet (2000) says that this is due to the desire

[21]See Shavell (1984).

not to encourage "economic waste".[22] If damages are simply an *ex post* transfer, this argument does not make a great deal of sense. Rather, the issue is the consequence of the damage award for *ex ante* incentives. In the context of our model of construction, such a rule is inefficient for Agent-biased tasks because it would result in too much investment by the contractor in cost reducing investments. If the Agent faces expectation damages, then he has an incentive to make efficient choices *ex post,* even when these choices might be different than the contract. This problem is illustrated in the famous case of Jacob & Youngs Inc. v. George E. Kent, 230 N.Y. 239 (1921).

Jacob and Youngs, a contractor, built a country residence for owners Kent at a cost of $77,000. Almost a year after work had ceased and after the owners had occupied the residence, the owners learned that the builders had failed to follow one of the contract specifications, and the owners refused to make the final payment due to the contractor. The contract stated that the plumbing work required the "standard pipe" of Reading manufacture. The builders had used pipes from other factories instead of using Reading-made pipes. The builders were asked by the owners to change the pipes, which was a problem since, in some places, the pipes were encased in the walls. The builders let these pipes remain untouched and asked for final payment, which the owners refused. Initially, the courts were consistent with the rule of specific performance (and classical contract theory) – the contractor was required to pay to the owners the cost of replacing the pipes. However, upon appeal, Judge Cardoza ruled that, since the replacement pipes were equivalent in quality to the specified pipes, there was no diminution in value, and hence Kent must make the final payment due to Jacob & Youngs. In the context of our model, $(u_H - u_L) < (c_H - c_L)$, and $F_u \simeq 1$. Hence, we are in the case of Agent-biased tasks, and damages should be $(u_H - u_L)$, as ruled by the courts.

This case is controversial because the contract terms are clear ($F_u \simeq 1$), and hence one would expect them to be enforced. However, the pipes used were equivalent in quality and did not affect the aesthetic qualities of the building, so one might argue that the contractor had, in fact, performed. Moreover, this encourages efficient decision making by the contractor, who can select materials of the appropriate quality at the lowest costs. This result also illustrates the point that, if the brand of pipe has an importance to the owner that is in addition to its properties as a transporter of water, then performance could have been ensured with the addition of liquidations damages that would have provided useful information to the Agent regarding the value of the pipe.[23]

The problem of ensuring performance is highlighted in the case of Peevyhouse v. Garland Coal Mining Co., 382 P2d. 109 (1962). The Garland Coal Mining Co. agreed to restore Peevyhouse's land after completing a strip-mining operation. Again, the contract was very clear on this point, yet the courts assessed expectation damages, which were far less than the cost of repairing the land. The history of the case is reviewed in Maute (1995), from which it appears to be quite clear that the landowner did, in fact, want the land returned to a better condition. The courts ruled that Garland had, in fact, breached the contract, but, since the land did not have great economic value, the measured damages were again given by $(u_H - u_L)$, approximately $5000 rather than the cost of performance $(c_H - c_L)$, estimated at about $29,000.

This case is controversial because it seems to demonstrate the impossibility of writing an *enforceable*

[22] Sweet (2000), page 532, states that in this case: "If the owner *did* correct defective work or complete the work when it would not be economically sound to do so, this would waste scarce societal resources."

[23] See Goldberg (1976) on the role of contracts in the transmission of information.

contract. The AIA form construction contracts provide guidance on how Peevyhouse could have written an enforceable contract. The root problem is that grading by itself is not a well-defined task; rather it requires monitoring to ensure proper execution. This would have been achieved with a separate contract for the grading work, under which Garland would have been required to post a bond in the event of nonperformance. This bond would have reallocated the *ex post* bargaining power to Peevyhouse, who could have then directed the grading in a way consistent with his preferences.

The right to direct changes in a construction process was affirmed in *Karz v. Department of Professional and Vocational Standards (1936) 11 CA 2d 554*, in which the owner and the contractor did not agree on the price for the extra work, but the contractor was required to perform the work or to be considered in breach of contract. The owner is still obliged to pay costs, but, if the contractor feels that the offered compensation is insufficient, then he can go to arbitration or to court to recover these costs.

5.2 Unforeseeable Events

If parties have sufficient foresight, then they could include liability terms that reflect both the value of a task and the degree of foreseeability. When parties do not, this task falls to the courts. It is interesting to observe that the courts do, in fact, modify expectations-damages as a function of the foreseeability of the task. This was established in the famous case of Hadley v. Baxendale (1854) 9 Exch 341. Before that time, a party who breached would be liable for the damages that she or he caused to the other party.

In *Hadley v. Baxendale*, the court ruled that liability should be limited to losses arising "according to the usual course of things" or to losses that "have been in contemplation of both parties, at the time they made the contract, as the probable result of the breach of it." The Hadley brothers, owners of City Flour Mills, wanted a broken shaft to be shipped by Pickford & Company, a common carrier, of which Baxendale was the managing director. The shaft was to be sent to Joyce & Co., Greenwich, manufacturers of the mill's steam engine. The broken shaft was supposed to be a model for a new one without which the mill could not operate. The shaft, which was supposed to be delivered by May 15, 1854, was not delivered until May 21. Baxendale was not informed about the high value of the product to Hadley; therefore, Baxendale did not take special precaution to ensure an on-time delivery. Hadley then sued Baxendale for the lost profits due to the delayed delivery.

The court held that Baxendale was not liable for Hadley's lost profits since the loss was due to unusual circumstances and since the damages to Hadley were unforeseen by Baxendale. In this case, it was agreed that the damages due to the late delivery, $u_H - u_L$, were large and possibly larger than the cost of taking action to avoid late delivery. However, these losses were unforeseen by Baxendale, and hence, under our optimal-liability rule, the damages due are $l^t = F_u(d^t)(u_H - u_L) = 0$.

More generally, our optimal rule highlights the importance of ensuring that the contract provides information to the Agent that allows for him to make efficient decisions. This result complements the analysis of Ayres and Gertner (1989) and of Bebchuk and Shavell (1991). They make the point that the rule of Hadley v. Baxendale provides incentives to buyers to reveal information regarding the value of service, which, in turn, induces sellers to take appropriate precautions. In our model, the degree of planning is endogenous, and hence limited liability follows from a lack of specificity regarding expectations.

5.3 Mistake

Similarly, our optimal rule can address the mistake excuse. If error in the contract leads to faulty performance or if, due to an error, the contracting parties have different understandings of the transaction, then non-performance may be excused. The mistake doctrine relates to a fundamental mistake of both parties as to the subject matter of the contract. If there is a fundamental mistake, then either contracting party can be excused of its performance. To get relief under the mistake doctrine, it is necessary that the mistake result in a contract. In Mannix v. Tryon (1907) 152 C 31, the court found that the decolorization of the structure constructed arose due to the specifications in the contract about the method used to mix plaster. The contractor was not held liable for the defect. Similarly, in McConnell v. Corona City Water Co. (1906) 149 C 60, the contractor was excused for the collapse of the tunnel since the contractor had followed the drawings, which were defective.

In another case, Sunbeam Construction Co. v. Fisci (1969) 2 CA3d 181, the contractor was not held liable for damages since the contractor performed as required by the contract and built a flat roof. The roof started leaking, and the contractor was not held responsible for not constructing a sloping roof to protect it from rain. Again, the design was poor, which led to no damages. In each of these cases, the harm was significant, but the mistake can be interpreted as $F_u(d) = 0$. Hence, the optimal damage is zero, consistent with the doctrine of excusing mistakes.

5.4 Impossibility

Impossibility (or frustration) is used to discharge a contract when the realized event had not been foreseen or anticipated. Very high realized costs may be used to excuse nonperformance in some cases. In Mineral Park Land Co. v. Howard (1916) 172 C 289, the costs were about ten-to-twelve-times higher than the anticipated costs, and the contractor was excused. The defendant had contracted to extract gravel and earth from the Park Land Co. at cost for the construction of bridges in Pasadena, California. P.A. Howard, however, did not take all of the required amount of gravel and earth from Park Land Co; he took it from a different source. Park Land Co. sued to recover the lost profits. The reason that the court excused the defendant was the extremely high cost of extraction, since, after a certain point, P.A. Howard would need to extract from below sea level using extraordinary means. The issue here appears to be that the performance of the contract required the execution of tasks unanticipated at the time that the contract was written (removal of gravel below sea level), and hence the Agent should not be required to execute these.

Under the optimal fixed-price contract, the Principal is required to pay for the cost of additional tasks, and the agent is free not to execute them should the costs of these tasks be greater than the Principal is willing to pay. This is different from simply making an error in estimated costs. In Kennedy v. Reece (1964) 225 CA2d 717, the contractor was not excused when the drilling costs went up from \$3.50 per foot to \$5 per foot. It is the responsibility of the contractor under a fixed-price contract to cover the costs of those tasks he has agreed to perform.

6 Discussion

Much of the literature on contract theory has focused on the implications of specific transaction costs, such as moral hazard or asymmetric information, on contract form and on how these transactions costs limit the abilities of parties to achieve efficient allocations.[24] It is typically assumed that, given the transactions costs, parties then choose an optimal contract. The evolution of the AIA form construction contract over time suggests that this is a rather strong hypothesis. Rather, this case illustrates that a contract can be viewed as part of the technology of exchange whose efficiency has improved over time as the result of competition in the market for form construction contracts. From this perspective, lawyers might be better viewed as engineers involved in the design of an instrument that enhances the efficiency of exchange.[25]

The incentive to provide a good contract arises from the competition for form construction contracts, that in turn provide incentives for suppliers of these forms to innovate and to improve their products over time. Given that the AIA form construction contracts have been widely used for over a century, we began with the hypothesis that, by this point, they must be doing something right. Our model of complex procurement illustrates that the AIA form construction contract can be viewed as an optimal solution to a contracting problem that combines two-sided holdup and asymmetric information regarding the Principal's preferences. We find, as with the property rights approach to the theory of the firm, that form construction contracts efficiently regulate the construction process via a carefully designed governance structure that allocates decision rights as a function of the characteristics of the different tasks needed to complete the project.

The salient features of the AIA contracts and the transaction costs they address can be summarized as follows:

1. As Bajari and Tadelis (2001) observe, project design is an investment decision. The use of competitive bidding to choose an Agent ensures that the Principal receives all of the marginal benefits for good design, and hence she has an incentive to invest optimally in design.

2. The default bargaining protocol assigns *ex post* authority to the Principal. This is efficient when it is assumed that the preferences of the Principal are private information; otherwise, authority would be allocated to the Agent. This authority is enforced by requiring the Agent to post a bond, combined with the threat of expropriating any of the Agent's assets on the work site.

3. Contractors are required to measure and to record construction costs.

4. The Agent is required to make minor changes at no cost when requested by the Principal. This ensures that the Agent prices the quality of design into the bid, which in turn provides the Principal with incentive to invest in design.

5. New, unforeseen tasks that are added to the project after the contract is signed are executed on a cost-plus basis.

[24]See Rogerson (1992) for a characterization of possible contracts when there is both asymmetric information and holdup.

[25]See Howarth (2004) who explicitly makes the point that most lawyers are not litigators; rather they, aid in the formation of contracts between commercial parties.

6. There is split authority. – Though the default rule is to grant the Principal authority, the Agent has explicit authority over many tasks, such as the organization of the work site, for which the Principal's preferences are less important. In order to ensure efficient decision making by the Agent, he is liable for defects and for variations from the original plan. The optimal liability rule is the degree of foreseeability on how to execute these tasks times the expectation value to the Principal.

These results illustrate that this class of contracts is constructed from a number of elementary institutions, including an auction mechanism, formal authority and cost sharing. They highlight the fact that observed contracts and contract incompleteness in particular cannot be understood as the solution to the existence of a single transaction cost but rather as the solution to the problem of regulating trade in the presence of several transaction costs.[26] However, even if one accepts that these contracts form an efficient solution to the problem of complex exchange, it does not follow that transactions costs alone can *explain* observed contract form. If this were the case, then we should observe similar form contracts in use world wide.

Rather, form construction contracts evolve in the shadow of the law and are designed to be enforceable in American courts. Hence, the solution to regulating transactions costs depends not only upon the characteristics of the good to be, but also upon the legal environment. A difficulty with the formal enforcement of contracts is that agents are always free to renegotiation contract terms, and hence in principle holdup is always a potential problem.[27] One of the lessons of this case study is that American courts appear to be aware of this problem, and they explicitly attempt to allocate authority to either the Principal or Agent depending upon the circumstance.

This tendency is not universal. Differences in the legal regimes governing construction contracts are discussed in a conference volume in honor of Justin Sweet.[28] For example, English contracts tend to be of a more contingent nature, with tasks defined explicitly *ex ante*. The commentators in this book suggest that the American contracts that allow more unilateral *ex post* modification to contract terms are superior to the ones used elsewhere. Though this claim is the result of casual empiricism, it does illustrate the existence of heterogeneity in the formation and enforcement of contracts, and it suggests that more work is needed before we fully understand the role of law in the formation of efficient contracts.[29]

[26]For example, Battigalli and Maggi (2003) show that writing costs by themselves are not sufficient to explain formal authority. In our model, formal authority arises from the combination of holdup and asymmetric information.

[27]See for example Hart and Moore (1988) in the context of fixed price contracts. Edlin and Hermalin (2000) extend this point to more complex contract forms such as option contracts.

[28]Odams (1995)

[29]This is unfortunately very little data with which one can address these issues. The only systematic study we know of is by Ashley and Mathews (1986). They carry out an interesting survey of construction contracts; however, their sample is very small and limited to members of the Construction Institute in Austin, Texas. Moreover, for the purposes of their analysis, they suppose that contracts are either fixed price or cost-plus. While this is a useful approximation, as we discussed above, observed contracts have much more complex structures.

A Proof of Propositions

A.1 Proposition 1

Since investment is bounded above by v_1^1 and since the reward function is continuous in $\{d^t, e^t\}$, this ensures the existence of optimal planning levels $\{d^{t*}, e^{t*}\}$. The function:

$$f(z_1, z_2, x_1, x_2) = z_1 z_2 + (1 - z_1)(1 - z_2) - x_1 - x_2,$$

is supermodular in $(z_1, z_2, x_1, x_2)$and increasing and convex in z_i, where $z_i \in [1/2, 1]$ and $x_i \geq 0$. Here, the lattice is defined on $\Re^2$ in the normal way, and $\{x, y\} \geq \{a, b\}$ if $x \geq b$ and $y \geq b$. The function $p_t(a)$ is increasing and supermodular in a, for $t = c, u$. Hence, by lemma 2.6.4 of Topkis (1998) this implies that:

$$v^t(d^t, e^t) = v_0^t + f(p_u(d^t), p_c(e^t), d^t, e^t),$$

is supermodular in $\{d^t, e^t\}$, and strictly supermodular for $\{d^t, e^t\} >> \{0, 0\}$.

The objective function exhibits increasing differences in v_1^t; therefore, the optimum $\{d^{t*}, e^{t*}\}$ is increasing with this variable. The payoff is convex for small v_1^t, and, by the upper-hemicontinuity of the solution as a function of v_1^t, there is a minimum level Δ, such that $d^{t*} = e^{t*} = 0$ for $v_1^t < \Delta$ and strictly positive for $v_1^t > \Delta$ (with two solutions when $v_1^t = \Delta$). We address uniqueness next. Since the payoff function is differentiable, it follows that, for $\{d^{t*}, e^{t*}\} > 0$, the first-order conditions 2 and 3 apply.

To solve equations 2 and 3, begin by letting $y_u(e)$ be the implicit solution to:

$$F_u'(y_u(e)) = \frac{2}{F_c(e)\, v_1^t}$$

This function, when defined, is differentiable, with first and second derivatives (the arguments have been left out to simplify the expressions):

$$\begin{aligned}
\frac{dy_u}{de} &= -\frac{1}{F_u''}\left\{\frac{2}{v_1^t F_c^2} F_c'\right\} > 0, \\
\frac{d^2 y_u}{de^2} &= \frac{1}{F_u''}\left\{-\frac{2}{v_1^t F_c^2} F_c'' + \frac{2}{v_1^t F_c^3}(F_c')^2 - F_u''' \frac{dy_u}{de}\right\} < 0.
\end{aligned}$$

A necessary condition for the existence of a strictly positive optimal investment level is:

$$F_u'(0) > \frac{2}{v_1^t},$$

from which it follows that there is a unique e_u solving:

$$F_u'(0) = \frac{2}{F_c(e_u)\, v_1^t}.$$

Let d_u solve $F_u'(d_u) = \frac{2}{v_1^t}$, then the curve $y_u(e)$ is shown in figure 1. The curve for $y_e(d)$ is similar. When a strictly positive optimum exists, the strict concavity (convexity) of these curves implies that they intersect in exactly two places, with the low intersection point corresponding to a local minimum arising from the local nonconcavity of the payoff function near $\{0, 0\}$. When v_1^t is sufficiently small, these curves will not intersect, and the unique optimum entails no investment.

A.2 Proposition 2

Under the cost-plus arrangement, the Agent is not rewarded for reducing costs, and hence $e^t = 0$. This implies that the Principal cannot be rewarded for design, and hence $d^t = 0$. Since out-of-pocket costs are reimbursed, the Agent's profit is P under this contract. She accepts any contract that results in $P \geq \Pi^0$, where Π^0 is the market profit rate. Hence, if $v_1^t \leq \Delta$ for all $t \in T$, then no investment is efficient, and the cost-plus contract induces the first best. Conversely, if $v_1^t > \Delta$ for some t, then it is optimal to have some investment for this task, in which case the cost-plus contract does not implement the first best.

A.3 Proposition 3

Suppose that the Agent knows Δu^t for every task t. Then, if the Principal has all of the bargaining power at the contract formation stage, then the Agent observes the Principal's valuations, u_H^t, u_L^t, *ex post.* If the Agent has all of the *ex post* bargaining power, then the fixed price contract with renegotiation implements the efficient allocation. Conversely, if the efficient allocation entails $d^{t*} > 0$ for some t and if the Principal has some *ex post* bargaining power ($\lambda < 1$), then the resulting allocation is inefficient.

The fact that the costs and benefits are common knowledge implies that *ex post* parties renegotiate to the efficient allocation, (It is a maintained hypothesis that costs are observed. — For the purposes of this proposition, benefits are also assumed observable). It is assumed that parties assign probability zero to the unforeseen events in T^U occurring, and hence they do not provide any *ex ante* incentives. For events in T, the following table specifies the amount of the price change for every state at which $q^t = 1$ is inefficient, and hence the contract needs to be renegotiated:

	Payoff at $q^t = 1$	Payoff at $q^t = 0$	Surplus
Principal-Biased	$\{u_L^t, c_H^t\}$	$\{u_H^t, c_L^t\}$	$\Delta u^t + \Delta c^t$
Tasks	$\{u_L^t, c_L^t\}$	$\{u_H^t, c_H^t\}$	$\Delta u^t - \Delta c^t$
Agent-Biased	$\{u_H^t, c_H^t\}$	$\{u_L^t, c_L^t\}$	$-\Delta u^t + \Delta c^t$
Tasks	$\{u_L^t, c_H^t\}$	$\{u_H^t, c_L^t\}$	$\Delta u^t + \Delta c^t$

Table 2: Renegotiated Prices When Design is Inefficient

In order to see how the entries are computed, consider the first case in which the net benefit from $q^t = 1$ is $u_L^t - c_H^t$. For Principal-biased tasks, it is efficient to execute $q^t = 0$ for a net benefit of $u_H^t - c_L^t$. This can be executed at a lower cost, and hence, when the Principal makes a take-it-or-leave-it offer, the Agent will agree to a price reduction of, at most, Δc^t; otherwise, he will insist on producing $q^t = 1$. Since the modification raises the Principal's utility by Δu^t, when the Agent has the bargaining power, he can extract a price increase of Δu^t from the Principal. The remaining entries are computed in a similar fashion. One can compute the *ex ante* expected payoffs of the Agent as a function of the initial price P and of the level of planning $\Pi = \{D, E\}$, and the renegotiation game will be as follows:

$$\begin{aligned} U^A(D,E,P) &= P - \sum_{t\in T}\left(c_H^t - \Delta c^t p_c\left(e^t\right) + e^t\right) \\ &\quad + \sum_{t\in T^P} \lambda\left(\Delta u^t + \Delta c^t\right)\left(1 - p_c(t)\right)\left(1 - p_u\left(d^t\right)\right) \\ &\quad \sum_{t\in T^P} \lambda\left(\Delta u^t - \Delta c^t\right) p_c(t)\left(1 - p_u\left(d^t\right)\right) \\ &\quad + \sum_{t\in T^A} \lambda\left(-\Delta u^t + \Delta c^t\right)\left(1 - p_c\left(e^t\right)\right) p_u\left(d^t\right). \\ &\quad \sum_{t\in T^A} \lambda\left(\Delta u^t + \Delta c^t\right)\left(1 - p_c\left(e^t\right)\right)\left(1 - p_u\left(d^t\right)\right) \end{aligned}$$

This summation is over all of the states, and it supposes that the parties renegotiate to the efficient allocation *ex post.*

At an interior optimum, the first-order condition for investment by the Agent in Principal-biased task is:

$$F_c'\left(e^t\right) = \frac{2}{\left(\lambda F_u\left(d^t\right) + (1-\lambda)\right)\Delta c^t} \leq \frac{2}{F_u\left(d^t\right)\Delta c^t}$$

The second inequality follows from the fact that $F_u\left(d^t\right) < 1$, and hence there is a strict inequality when $\lambda < 1$ and equality when $\lambda = 1$. At the optimum, $F_c'' < 0$, and hence, given the conditions for the first based in proposition 1, the Agent invests efficiently, if and only if, $\lambda = 1$. When the Principal has some bargaining power, the Agent *overinvests* in cost reduction. For Agent-biased tasks, one has a similar result since the first-order conditions are given by:

$$F_c'\left(e^t\right) = \frac{2}{\lambda F_u\left(d^t\right)\Delta u^t + (1-\lambda)\Delta c^t} \leq \frac{2}{F_u\left(d^t\right)\Delta u^t},$$

with strict inequality when $\lambda < 1$ (note that $\Delta u^t < \Delta c^t$ in this case).

Since the Principal has all of the bargaining power *ex ante* and since design is observed before the Agent makes his investment, design is efficient given the behavior of the Agent. Given that design and cost reduction are complementary, when the Agent overinvests, the Principal also overinvests in design relative to the first best.

A.4 Proposition 4

In this case, when the Agent makes an offer, he does not know the valuation of the Principal, and hence he offers a price change that is rejected with positive probability. Consider, first, the case of a Principal-biased task (Agent-biased tasks will be similar). When the benefit and cost of $q^t = 1$ is $\{u_L^t, c_H^t\}$, the Principal will accept δp^t if and only if $\delta p^t \leq \Delta u^t$. Thus, the gain to the Agent from this offer is:

$$\Delta U_A^t\left(\delta p^t\right) = \left(\delta p^t + \Delta c^t\right)\int_{\delta p^t}^{m^t} g(x)\,dx.$$

Since $g(x)$ is continuous, the solution $\delta p^{t*}$to $\max_{\delta p^t} \Delta U_A^t\left(\delta p^t\right)$ satisfies $g\left(\delta p^{t*}\right) > 0$, from which we conclude that there is a strictly positive probability that the offer will be rejected, even though it is efficient for renegotiation to occur.

A.5 Proposition 5

Since the Principal has authority for Principal-biased tasks, she will make an efficient decision *ex post.* For agent-biased tasks, regardless of the source of the design uncertainty, it is the case that:

$$l^t \leq \Delta u^t < \Delta c^t,$$

and therefore the Agent selects the low-cost task, which is the efficient choice in this case. Any new tasks in T^U are on a cost-plus basis, so the Agent is indifferent regarding their execution. Hence, the Principal chooses the efficient action for these tasks. Therefore, this contract ensures efficient production *ex post.* Given this, the Agent selects his cost reducing investment as follows: – For Principal-biased tasks, he anticipates the likelihood of a design change, and, since his income does not vary with costs, the Agent chooses e^t to satisfy:

$$\min_{e^t \geq 0} \gamma \left(d^t, e^t\right) \Delta c^t,$$

where d^t is the level of design by the Principal, which is the efficient level of investment given d^t. Let $e^t\left(d^t\right)$ be the solution to this problem.

In the case of Agent-biased tasks, consider first the case of cost uncertainty. The case for contract uncertainty is similar. The Agent selects investment to minimize liability, and hence he chooses e^t for $t \in T^A$ to minimize liability:

$$\min_{e^t \geq 0} \left\{\left(1 - p_e\left(e^t\right)\right) l_s^t - e^t\right\}, \text{ or}$$
$$p'_e\left(e^t\right) = \frac{1}{l_s^t}.$$

Let $e^t\left(l_s^t\right)$ be the solution to this problem. The cost of the project for the Agent as a function of contract terms (leaving out T^U, which are unanticipated and hence do not affect *ex ante* actions) is given by:

$$\begin{aligned} C(D,L) &= \sum_{t \in T^P} c_L^t + \gamma\left(d^t, e^t\left(d^t\right)\right) \Delta c^t \\ &+ \sum_{t \in T^A} c_L^t + \left(1 - p\left(e^t\left(l_s^t\right)\right)\right) l_s^t. \end{aligned}$$

Given that the market is competitive, the firms will bid a price $P = \Pi^0 + C(D,L)$, where Π^0 is the return on the next best project. Hence, the payoff function for the Principal is:

$$\begin{aligned} U^P\left(D, T^P, T^A, L\right) &= \sum_{t \in T^P} u_H^t + \sum_{t \in T^A} u_L^t + \gamma\left(d^t, e\left(d^t\right)\right) \Delta u^t \\ &- P^0 - C(D,L). \end{aligned}$$

In the case of Principal-biased tasks, the Agent is making an efficient decision given design, and, since the Principal is paying the full cost due to the competitive bidding assumption, design is efficient. In the case of Agent-biased tasks, the Principal is able to fully control investment via l_s^t, and again she will select design and liability efficiently since she faces the full marginal return from any decision. The formula for efficient cost reducing investment with cost uncertainty follows from 3:

$$l_s^t = \frac{1}{p'_e\left(e^{t*}\right)} = F_u\left(d^{t*}\right) \Delta u^t.$$

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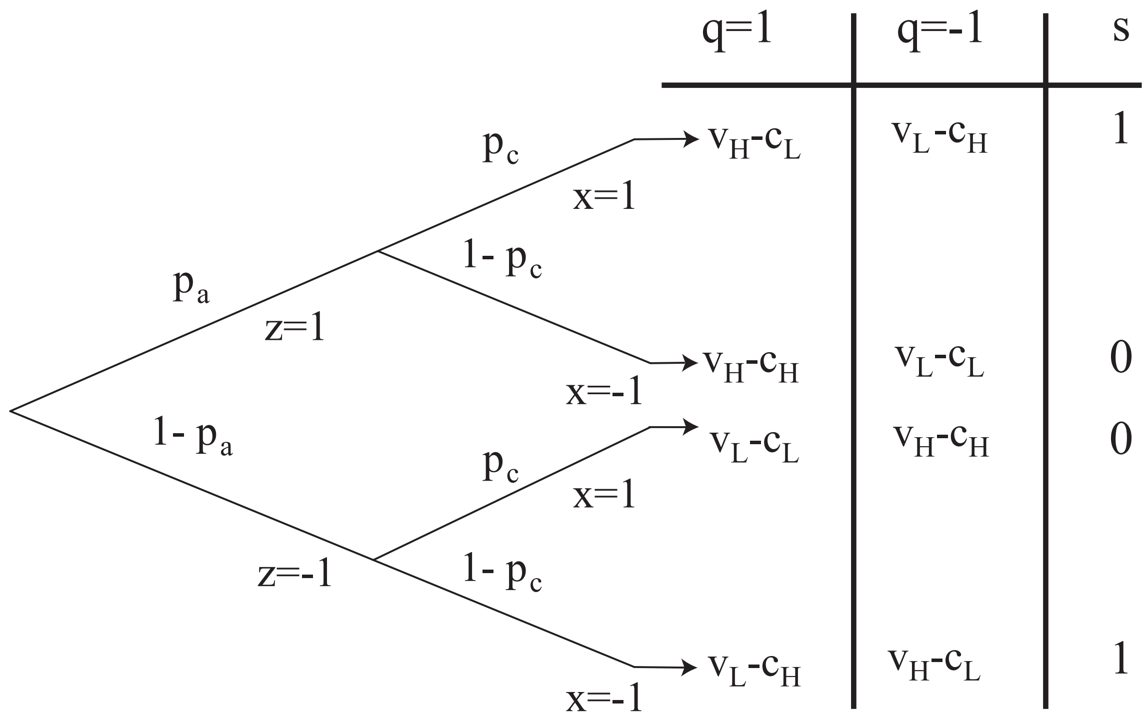


Figure 1: Surplus as a Function of the State

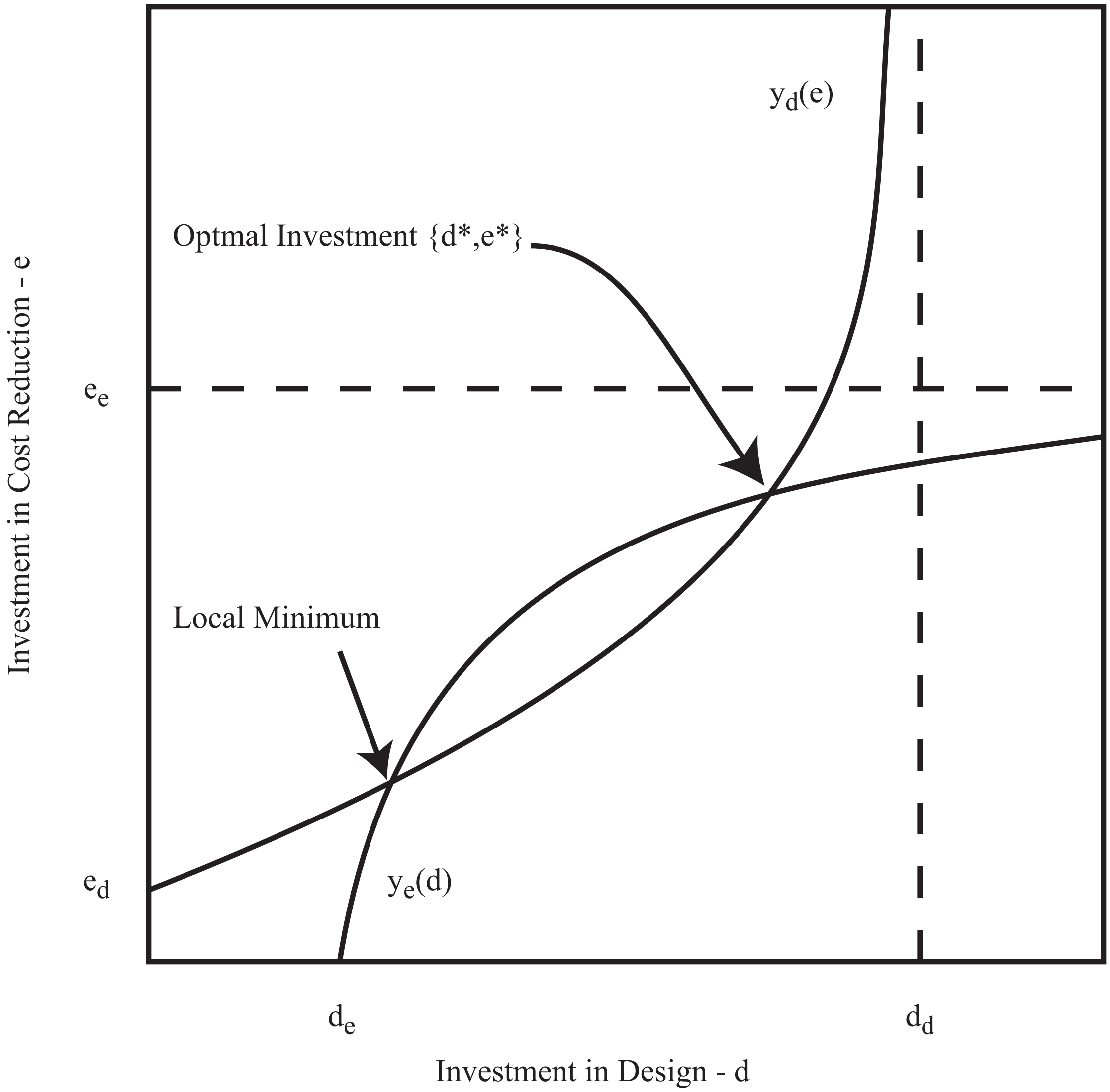
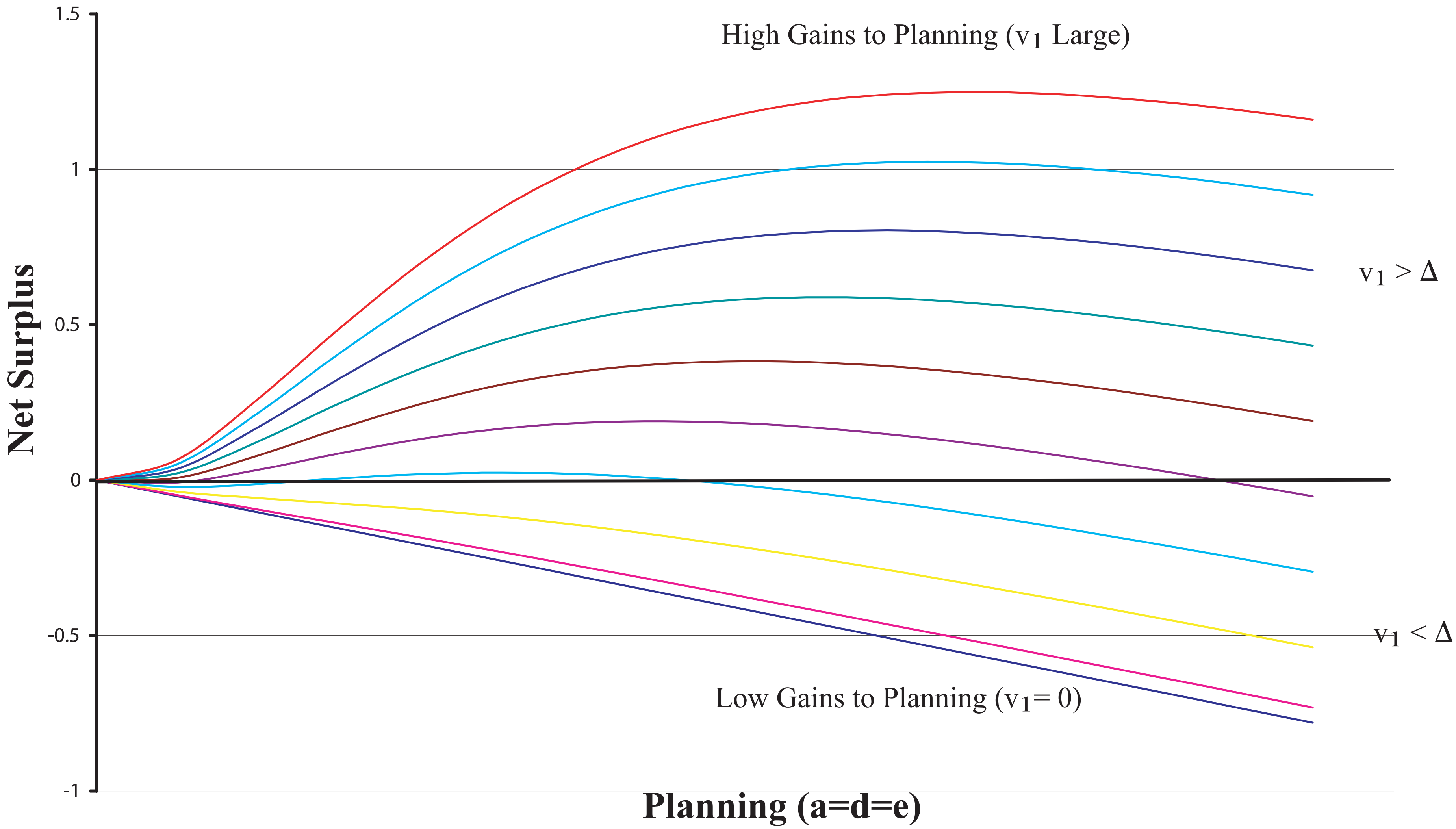


Figure 2: Optimal Investments in Design and Cost Reduction

Figure 3: Surplus vs. Planning



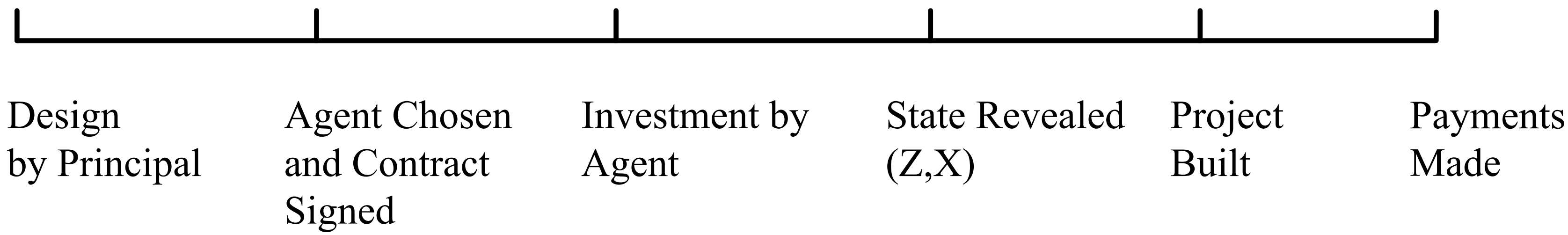


Figure 4: Time Line for Contract Formation and Performance

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