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The role of installment payments in contracts for services

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This article studies the role of installment payments in relationships characterized by moral hazard and sunk costs. We rule out vertical integration and payments contingent on the product of the contractor. Instead, each payment is negotiated as and when made. In such circumstances, an initial (down)payment serves to redress the weakness of the contractor in ex post *renegotiations. If higher effort by the contractor in the first stage increases the marginal product of effort in the second stage, a second installment payment induces the contractor to invest greater effort initially.*

1. Introduction

■ A substantial and growing share of the national product of a developed economy consists of services such as construction and engineering work, professional services such as legal advice and representation and management consultancy, and creative work such as architectural design, the writing of software, preparation of advertisements, and research and development.

Two potential hazards may complicate contracts for such services. The first is shirking by the contractor, which arises where it is costly for the buyer to monitor the contractor's effort, or where it is costly to provide for all possible contingencies in an explicit contract. Recognizing *ex ante* the potential for shirking, the value of the project to the buyer will be smaller than if the contractor could commit credibly not to shirk. Moreover, *ex post*, if the buyer detects or suspects shirking by the contractor, she may demand to be compensated. Such a demand will in effect lead to *ex post* renegotiation of the price for the contract.

Another distinctive feature of the provision of services is that once incurred, most of the cost of the service may be sunk. This is especially true of professional services and commissioned creative work such as architectural design and the preparation of an advertising campaign, and true to a lesser extent of engineering and construction work. Because his costs are sunk, the contractor's bargaining position in *ex post* renegotiations of the contract

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price will be relatively weak. Thus, the second hazard is that the prospect of *ex post* renegotiation may deter contractors from entering into otherwise profitable transactions.

In such circumstances, if the realized value to the buyer of the effort invested by the contractor, i.e., the value of the contractor's product, may be verified by a court at low cost, then the parties may negotiate a contract in which the contractor's compensation depends on the product. The work of Grossman and Hart (1983), Lambert (1983), Mookherjee (1984), Fellingham, Newman, and Suh (1985), and Fudenberg, Holmström, and Milgrom (1987) studies the character of such contracts. In reality, however, it may be very difficult for courts to verify the value to the buyer of the contractor's effort. This is especially true of services such as building construction, legal representation, and commissioned software; by the very nature of the product, it is unique and may be of idiosyncratic value to the buyer. The cost of third-party enforcement may well explain the observation of Macauley (1963) that businessmen resort to third-party enforcement only to a limited degree.

Klein, Crawford and Alchian (1978), and Williamson (1975), argue that, instead of relying on detailed and complex contracts, the parties may vertically integrate, thereby ameliorating the conflict of interest and so reduce shirking and *ex post* opportunistic renegotiations. The law forbids victims of automobile accidents from selling their tort claims to third parties such as attorneys, so in these cases, vertical integration is illegal. In other cases, it may be impossible for the agent to achieve the same utility as would the principal: for instance, a building contractor very likely will not enjoy every house that he constructs as much as would the various employers who hire him.

In this article we focus on the nature of contractual arrangements where the parties cannot condition payments on the buyer's value and cannot integrate vertically. Observing that schemes of installment payments appear to be ubiquitous in contracts for services, we speculate that they serve other functions besides finance of work-in-progress. We shall consider whether (and if so, how) the use of installment payments may mitigate the problems of moral hazard and sunk costs.

In order to specify payments that are renegotiation-proof, we assume that payments are negotiated only as and when they are made. We model the negotiation of the payments by way of the generalized Nash bargaining solution. We show that an initial downpayment, paid before the contractor begins work, serves to redress the weakness of the contractor in *ex post* renegotiations, and in particular, is necessary and sufficient to ensure that, given the effort subsequently chosen by the contractor, any project that will provide gains from trade will proceed.

Considering projects in which there are two stages of work, we show that a contract under which the contractor is paid in installments (before the first stage of work, between the two stages, and again upon completion of the work) will elicit more effort from him than a contract under which he is paid only at the beginning and upon completion of the work. Under both contracts, the final payment depends on the value of the product to the buyer, hence providing the contractor with some incentive for effort in both stages.

Installment payments add to these incentives because, in equilibrium, the second installment increases with the effort chosen by the contractor in the second stage. We assume that the contractor's efforts in the two stages are complements in the sense that higher effort by the contractor in the first stage increases the marginal product of effort in the second stage. Hence, the contractor will choose higher effort in the first stage in order to *commit* to higher effort in the second stage, thereby raising the second installment payment. By providing an additional reward for higher effort in the second stage, the second installment motivates higher effort in the first stage. Understanding this incentive effect, the buyer will agree to a second installment, and indeed, both parties gain from the payment of that installment.

In related work, Pearce and Stachetti (1988) consider the interaction between contractual and noncontractual payments in a long-term relationship between a risk-neutral principal and risk-averse agent. The two parties can only partially condition payments on the output of the agent. In equilibrium, the principal uses payments conditioned on output to encourage effort by the agent, and couples these with unconditional payments to mitigate risk borne by the agent. Our findings complement theirs by demonstrating a role for payments not conditioned on output even if both parties are risk neutral, but provided that the effort of the agent is sunk once it is incurred.

Fershtman (1990) analyzes bargaining between two players to divide a sequence of two pies of fixed size. Both players are impatient, and share a common discount factor. No player may enjoy either pie until both have completed negotiations over both pies. All information—including each player's valuation of the two pies—is common knowledge. The players bargain noncooperatively as in Rubinstein (1982), so that at any stage the player making the offer will extract a larger portion of the pie. Fershtman shows that each player prefers to bargain first over the pie that is less valuable to him. By contrast, we consider a setting in which there is only one pie, the value of which depends on the noncontractable effort of one party. We focus attention on the effects of a sequence of negotiated payments on incentives for effort and to enter into contract. For simplicity, we abstract from the effects of discounting.

The model is presented in Section 2. We characterize the contractor's effort and profit under a lump-sum scheme in Section 3, and the effort and profit under an installment scheme in Section 4. In Section 5, we compare effort and profits under the two schemes for a project with two stages of work. Section 6 describes features of the law governing construction and engineering contracts that illustrate our analysis, and Section 7 contains concluding remarks.

2. Model

■ Consider some service which is provided naturally in a sequence of stages $j = 1, \ldots, n$. Examples include legal representation, which begins with an action by a plaintiff, appearance by the defendant, followed by pleadings, discovery, trial, and appeal; the development of software, beginning with a prototype, which is operationalized, and finally tested; and the construction of buildings, which commences with preparation of the site, then continues to the foundation, the structure, etc. The stages are defined by the verifiability of completion: because it is easy for courts to verify that a prototype is complete, while it is relatively more difficult to verify that a prototype is one-third complete, completion of the prototype constitutes one stage.

At each stage j, the contractor must choose some degree of effort e_j. We assume that there is some minimum degree of effort that courts may verify at very low cost. Hence, moral hazard arises only in the range of effort above that limit. A court will find that a stage is complete provided that the contractor has met the minimum effort.

Let the (incremental) cost to the contractor of effort e_j be $c_j(e_j) > 0$, where $c_j(\cdot)$ is increasing and weakly convex in e_j. Assume that this cost has no salvage value, i.e., it is sunk once incurred in the project. Denote the cumulative cost up to stage j, $C_j(e_1, \ldots, e_j) \overset{\text{def}}{=} \sum_{i=1}^{j} c_i(e_i)$.

In legal representation, creative work (such as the writing of software, preparation of an advertising campaign, and contract research and development) and design work (such as architectural and interior design), the value to the buyer of incomplete work by the contractor is minimal. With this motivation, we assume that the value to the buyer of the contractor's effort is zero except on completion of stage n. Let the value of the product after stage n be $B_n(e_1, \ldots, e_n)$, where $B_n(\cdot)$ is continuous, increasing, and strictly concave in $(e_1, \ldots, e_n)$. For brevity, we will let $C_j = C_j(e_1, \ldots, e_j)$ and $B_n = B_n(e_1, \ldots, e_n)$ wherever it will not give rise to misunderstanding.

In many circumstances, it is natural not only that the benefit, B_n, be increasing in the effort of each stage, but in addition, that the *marginal* benefit be increasing in the effort of the contractor in the preceeding stages. For instance, under the rules of civil procedure, counsel in an appeal may argue only those issues disputed at trial, hence the marginal benefit of effort in the appeal stage will be higher if the lawyers had invested effort in raising all relevant issues at trial. Similarly, the marginal benefit of effort in building an above-ground structure will be higher if the contractor had used more effort in laying the foundation. In light of this, we make the following assumption.

Assumption. (Forward Intertemporal Complementarity of Effort.)

$$\frac{\partial^2 B_n}{\partial e_i \partial e_j} \geq 0,$$

for $1 \leq i < j \leq n$. Since $B_n(e_1, \ldots, e_n)$ is continuous, this implies that

$$\frac{\partial^2 B_n}{\partial e_i \partial e_j} \geq 0,$$

all $i \neq j$.

We assume that both buyer and contractor can observe the effort e_j chosen by the contractor in each stage, the incremental cost, $c_j(e_j)$, and the benefit to the buyer of the completed product, B_n. We assume, however, that because of the high cost of proof to independent third parties such as courts, the parties cannot contract on e_j, $c_j(e_j)$, or B_n.[1]

The buyer and contractor, however, can observe and contract on the completion of each *stage*. Given the sequence of physical stages, the parties can agree and contract in advance on the stages at which payments will be made.

In principle, the buyer and contractor could also contract in advance on the amounts of the payments at each stage. At the time for each payment, however, the buyer could raise objections with regard to shirking by the contractor and threaten to sue the contractor for damages. Rather than go to court, the buyer and contractor may renegotiate the contracted-upon payment and settle out of court. To capture this in a simple way, we assume that the buyer and contractor do not negotiate in advance on payments, but instead negotiate payments only as and when they are made. Each payment may be conditioned only on the completion of the stages of work until the subsequent payment.

We model the negotiated payments by way of the generalized Nash bargaining solution. Let the bargaining strength of the buyer be $\beta > 0$, and the bargaining strength of the contractor be $\gamma > 0$.

To provide a convenient point of reference, we characterize the first-best degree of effort, $(e_1^*, \ldots, e_n^*)$, which solves the following problem:

$$\text{Max } B_n(e_1, \ldots, e_n) - C_n(e_1, \ldots, e_n).$$

Since $C_n(e_1, \ldots, e_n) = \sum_{j=1}^{n} c_j(e_j)$, the effort e_j^* is characterized by the first-order condition

$$\frac{\partial B_n}{\partial e_j}(e_1^*, \ldots, e_{j-1}^*, e_j, e_{j+1}^*, \ldots, e_n^*) - c_j'(e_j) = 0, \tag{1}$$

for $j = 1, \ldots, n$. Any project that satisfies

$$B_n(e_1^*, \ldots, e_n^*) - C_n(e_1^*, \ldots, e_n^*) \geq 0 \tag{2}$$

should be undertaken.

[1] In the standard principal-agent model, the principal and agent may not contract on the agent's effort, but the principal knows the agent's utility function and hence can infer the effort that the agent will select.

3. Lump-sum scheme

■ The simplest contract is one in which the buyer makes a single lump-sum payment to the contractor at the end of all n stages. Let the contractor choose effort $(e_1, \ldots, e_n)$. Then the value of the product to the buyer will be $B_n(e_1, \ldots, e_n)$, and the accumulated cost to the contractor will be $C_n(e_1, \ldots, e_n)$.

Upon completion of the product, the buyer and contractor must negotiate a payment. If they agree on a payment, p, the project will be handed over, and the buyer will enjoy net profit $B_n(e_1, \ldots, e_n) - p$, and the contractor will receive $p - C_n(e_1, \ldots, e_n)$. If the buyer and contractor cannot agree, the buyer will not receive the project and have zero benefit. Because the project has no salvage value for the contractor, the contractor's profit will be $-C_n(e_1, \ldots, e_n)$. By the generalized Nash bargaining solution, the payment p solves the problem

$$\text{Max } [B_n(e_1, \ldots, e_n) - p]^\beta \cdot [(p - C_n(e_1, \ldots, e_n)) - (-C_n(e_1, \ldots, e_n))]^\gamma .$$

The solution is

$$p = \frac{\gamma}{\beta + \gamma} B_n(e_1, \ldots, e_n). \tag{3}$$

This payment depends on the benefit, B_n, of the completed product to the buyer. The greater the buyer's bargaining strength, β, and the smaller the seller's bargaining strength, γ, the larger the buyer's share of this benefit. The payment does not depend on C_n because that is sunk cost at the time of negotiation. Thus, at the outset, the buyer expects to receive a total profit of

$$B_n(e_1, \ldots, e_n) - p = \frac{\beta}{\beta + \gamma} B_n(e_1, \ldots, e_n)$$

by the end of the project, and the contractor will expect a total profit of

$$p - C_n(e_1, \ldots, e_n) = \frac{\gamma}{\beta + \gamma} B_n(e_1, \ldots, e_n) - C_n(e_1, \ldots, e_n).$$

Hence, at the outset, the contractor will choose effort $(\hat{e}_1, \ldots, \hat{e}_n)$ to

$$\text{Max } \frac{\gamma}{\beta + \gamma} B_n(e_1, \ldots, e_n) - C_n(e_1, \ldots, e_n).$$

Effort under the lump-sum contract, $\hat{e}_j$, is characterized by

$$\frac{\gamma}{\beta + \gamma} \frac{\partial B_n}{\partial e_j} (\hat{e}_1, \ldots, \hat{e}_{j-1}, e_j, \hat{e}_{j+1}, \ldots, \hat{e}_n) - c_j'(e_j) = 0, \tag{4}$$

for $j = 1, \ldots, n$. Under a lump-sum scheme, the contractor expects to receive a payment that is a fraction of the total benefit to the buyer, hence the contractor is provided with some incentive for effort. Because the contractor does not capture all the marginal benefit from his effort, he will be led to choose effort less than first best, $\hat{e}_j < e_j^*$, for $j = 1, \ldots, n$. This is the moral hazard problem.

The buyer and contractor will proceed with the project under the lump-sum scheme if and only if

$$\frac{\beta}{\beta + \gamma} B_n(\hat{e}_1, \ldots, \hat{e}_n) \geq 0, \tag{5}$$

and

$$\frac{\gamma}{\beta + \gamma} B_n(\hat{e}_1, \ldots, \hat{e}_n) - C_n(\hat{e}_1, \ldots, \hat{e}_n) \geq 0. \tag{6}$$

Notice that by the definition of $(e_1^*, \ldots, e_n^*)$,

$$B_n(e_1^*, \ldots, e_n^*) - C_n(e_1^*, \ldots, e_n^*) \geq B_n(\hat{e}_1, \ldots, \hat{e}_n) - C_n(\hat{e}_1, \ldots, \hat{e}_n)$$

$$\geq \frac{\gamma}{\beta + \gamma} B_n(\hat{e}_1, \ldots, \hat{e}_n) - C_n(\hat{e}_1, \ldots, \hat{e}_n),$$

hence there are projects that would yield gains from trade at the first-best level of effort that will not be undertaken because they do not meet condition (6).[2] Moreover, there are projects that would yield gains from trade at the given effort $(\hat{e}_1, \ldots, \hat{e}_n)$ that also will not be undertaken. This is the sunk-cost problem.

We next show that a simple remedy for the problem of sunk costs would be for the parties to negotiate downpayment in advance of commencement of the work. Consider negotiations for a preliminary payment, d, that is conditional only on completion of all n stages of the project. If the parties agree in these negotiations, they will expect to move to the completion of the project. Thus, if the parties agree, the buyer will expect a final profit of $B_n - d - p$, and the contractor will expect a final profit of $d + p - C_n$.

If the parties cannot agree in the preliminary negotiations, the project will not proceed, and both buyer and contractor will incur no cost and receive nothing. Therefore, by the generalized Nash bargaining solution, the downpayment d solves the problem

$$\text{Max } [B_n - d - p]^\beta \cdot [d + p - C_n]^\gamma.$$

Simplifying,

$$d + p = \frac{\gamma B_n + \beta C_n}{\beta + \gamma}, \tag{7}$$

and substituting for p from (3), we have

$$d = \frac{\beta}{\beta + \gamma} C_n. \tag{8}$$

It may seem paradoxical that the weaker the contractor's bargaining power, γ, the larger the downpayment, d. The explanation rests in the contractor's expectations about subsequent stages (see (7)). The greater the buyer's bargaining power, the smaller the end-of-project payment, p, to the contractor. So to partially offset the weakness of the contractor's bargaining position in *ex post* negotiations, the contractor will demand and obtain more in downpayment, as condition for incurring the cost, C_n. Since this will be sunk once incurred, the buyer will be willing to contribute to it only in advance.

Notice that the downpayment is conditional only on completion of the project. From the contractor's standpoint, it is essentially a lump-sum payment and does not affect his choice of effort, which remains $(\hat{e}_1, \ldots, \hat{e}_n)$. Thus, substituting in (5) and (6), the total profit expected by the buyer at the outset of the project will be

$$\frac{\beta}{\beta + \gamma} [B_n(\hat{e}_1, \ldots, \hat{e}_n) - C_n(\hat{e}_1, \ldots, \hat{e}_n)], \tag{9}$$

and the total profit expected by the contractor will be

$$\frac{\gamma}{\beta + \gamma} [B_n(\hat{e}_1, \ldots, \hat{e}_n) - C_n(\hat{e}_1, \ldots, \hat{e}_n)]. \tag{10}$$

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[2] Moral hazard gives rise to the first inequality.

By (9) and (10), the parties will agree to proceed on any project that satisfies

$$B_n(\hat{e}_1, \ldots, \hat{e}_n) - C_n(\hat{e}_1, \ldots, \hat{e}_n) \geq 0.$$

So, although the downpayment does not affect the contractor's incentives for effort, it does shift part of the cost onto the buyer. By improving the division of the pie in this way, the inclusion of a downpayment ensures that, given the contractor's effort $(\hat{e}_1, \ldots, \hat{e}_n)$, any project that will provide gains from trade will proceed. Consequently, more projects will be undertaken.

Proposition 1. The inclusion of a downpayment prior to the commencement of work is necessary and sufficient to ensure that, given the effort chosen by the contractor, any project that will provide gains from trade will proceed.

Proof. A downpayment is necessary because, without it, there are projects that provide gains from trade that will not proceed under either the lump-sum scheme or the installment scheme.[3] By (9) and (10), inclusion of a downpayment suffices to resolve the sunk cost problem. *Q.E.D.*

In the next section we investigate how the use of installment payments may mitigate both moral hazard and sunk costs.

4. Installment scheme

■ We now consider the effect of installment payments on the contractor's incentives for effort, and on the total payment received by the contractor. We assume that at the beginning of every stage of work, the parties negotiate an installment payment that is conditional on the contractor's completion of the subsequent stage. The sequence of events in each stage $j = 1, \ldots, n$ is as follows: first, the parties negotiate an installment payment, d_j, and then the contractor invests effort, e_j.[4] On completion of the nth stage, the parties negotiate a final payment, p, and if they agree, the contractor will hand over the completed project to the buyer.

In the negotiations after completion of the project, if the parties agree, the buyer will receive the completed product, and realize a total profit of $B_n - \sum_{i=1}^{n} d_i - p$, and the contractor will receive a total profit of $\sum_{i=1}^{n} d_i + p - C_n$. If the parties cannot agree, the buyer will be left with a loss of $\sum_{i=1}^{n} d_i$, i.e., a profit of $-\sum_{i=1}^{n} d_i$, and the contractor will be left with a total profit of $\sum_{i=1}^{n} d_i - C_n$. For purposes of the generalized Nash bargaining solution, these conditions are essentially identical to those that determine the final payment under the lump-sum scheme, hence the final payment under the installment scheme must be an identical function of the contractor's effort,

$$p = \frac{\gamma}{\beta + \gamma} B_n.$$

If the parties agree in the beginning-of-stage-j negotiations, they expect to move to the end of the jth stage. Now, in equilibrium, the parties will agree in every stage, hence agreement in any stage will imply the rational expectation of continuation along the equilibrium path, which culminates in the completion of the project at the nth stage. Thus, if the parties agree

[3] See below for claim about installment scheme.

[4] The first installment payment, d_1, would be the downpayment.

at the beginning of stage j, the buyer will expect a final profit of $B_n - \sum_{i=1}^{n} d_i - p$, and the contractor will expect a final profit of $\sum_{i=1}^{n} d_i + p - C_n$, and not merely the respective profits up to the end of the jth stage.

If the parties cannot agree in the beginning-of-stage-j negotiations, the buyer will not receive anything from the contractor and hence will be left with a total profit of $-\sum_{i=1}^{j-1} d_i$, while the contractor will be left with a total profit of $\sum_{i=1}^{j-1} d_i - C_{j-1}$. Therefore, the installment payment d_j solves the problem

$$\text{Max } [B_n - \sum_{i=j}^{n} d_i - p]^{\beta} \cdot [\sum_{i=j}^{n} d_i + p - C_n + C_{j-1}]^{\gamma},$$

for $j = 1, \ldots, n$. In Proposition 2, we show that the equilibrium installment payments are

$$d_j = \frac{\beta}{\beta + \gamma} c_j(e_j).$$

Since courts and other third parties cannot observe the contractor's effort, the installment payment d_j at the opening of stage j cannot be *contractually* conditioned on the effort of the contractor in stage j or later stages.[5] In *equilibrium,* however, the buyer and contractor will agree on an installment payment that depends on the effort, e_j, that both parties rationally *expect* the contractor to select at stage j.

At the beginning of stage j, the cumulative profit of the contractor from that point onward is

$$\sum_{i=j}^{n} d_i + p - C_n + C_{j-1} = d_j + \sum_{i=j+1}^{n} \frac{\beta}{\beta + \gamma} c_i(e_i) + \frac{\gamma}{\beta + \gamma} B_n(e_1, \ldots, e_n) - \sum_{i=j}^{n} c_i(e_i).$$

Since each installment payment, d_j, is a lump sum contingent only on the completion of stage j, it does not affect the contractor's choice of effort, $\tilde{e}_j$, at that stage. Let

$$e^j \stackrel{\text{def}}{=} (e_1, \ldots, e_j),$$

represent the contractor's effort up to and including stage j. Then, in stage j, the contractor will choose effort $\tilde{e}_j$ to

$$\text{Max } \frac{\gamma}{\beta + \gamma} [B_n(e_1, \ldots, e_{j-1}, e_j, e_{j+1}(e^j), \ldots, e_n(e^{n-1})) - \sum_{i=j+1}^{n} c_i(e_i(e^{i-1}))] - c_j(e_j),$$

for $j = 1, \ldots, n$.

Proposition 2. Under an installment scheme, the installment payment at the beginning of stage j is

$$d_j = \frac{\beta}{\beta + \gamma} c_j(\tilde{e}_j), \tag{11}$$

and the final payment at the end of stage n is

$$p = \frac{\gamma}{\beta + \gamma} B_n(\tilde{e}_1, \ldots, \tilde{e}_n), \tag{12}$$

[5] This enables a major simplification in the analysis—the bargaining over installments may be separated from the effect of the payments scheme on incentives for effort.

where

$$\tilde{e}_j = \text{argmax}\left\{\frac{\gamma}{\beta+\gamma}\left[B_n(e_1,\ldots,e_{j-1},e_j,e_{j+1}(e^j),\ldots,e_n(e^{n-1}))\right.\right.$$
$$\left.\left.-\sum_{i=j+1}^{n} c_i(e_i(e^{i-1}))\right] - c_j(e_j)\right\}, \quad (13)$$

for $j = 1, \ldots, n$.

Proof. See Appendix.

Although the incentive for the parties to agree in stage j is to be able to progress to the final stage, the installment payment d_j depends only on the incremental cost incurred in stage j. By assumption, the parties cannot commit to a payment that depends on the incremental cost of subsequent stages. The installment payments serve two functions: first, they redress the weakness of the contractor in *ex post* negotiations by partially compensating for the sunk costs to be incurred, and second, they affect the contractor's incentives for choice of effort.

If the buyer did not make the installment payments, d_j, the cumulative profit of the buyer from the beginning of stage j onward would be

$$\frac{\beta}{\beta+\gamma} B_n,$$

and the cumulative profit of the contractor from that point onward would be

$$\frac{\gamma}{\beta+\gamma} B_n - (C_n - C_{j-1}).$$

The inclusion of the installment payments of $d_j = \frac{\beta}{\beta+\gamma} c_j(e_j)$, reduces the buyer's cumulative profit to

$$\Pi_j^B = \frac{\beta}{\beta+\gamma}[B_n - (C_n - C_{j-1})], \quad (14)$$

and increases the contractor's cumulative profit to

$$\Pi_j^C = \frac{\gamma}{\beta+\gamma}[B_n - (C_n - C_{j-1})]. \quad (15)$$

Thus, $\Pi_j^B \geq 0$ and $\Pi_j^C \geq 0$ if and only if $B_n \geq C_n - C_{j-1}$, i.e., the installments ensure that a project will continue if and only if continuation would provide gains from trade.

From the perspective of the contractor at stage j, his choice of effort e_j influences his effort, e_k, in subsequent stages $k > j$, through its effect on the marginal benefit of effort in subsequent stages, $\partial B_n/\partial e_k$. By (13), we observe that, under the installment scheme, the contractor choosing effort at stage j rationally expects the buyer to bear part of the subsequent cost $c_k(e_k)$, $k > j$ through the subsequent installment payments. The installment scheme affects the contractor's choice of effort through this mechanism. Notice from (4), however, that this effect does not arise under the lump-sum scheme.

5. Lump-sum versus installment schemes

■ Our central concern is the effect of schemes of installment payments on the contractor's incentives for effort and the contractor's willingness to undertake projects. Owing to the difficulty of characterizing in general the effect of changes in the installment scheme, we focus on the case of two stages of work, i.e., $n = 2$.[6] We compare the contractor's effort and total profit under two schemes: (i) a lump-sum scheme, with an initial (down)payment before the first stage and a final payment after the two stages; and (ii) an installment scheme with an initial (down)payment, a (second) installment payment, and a final payment, i.e., one payment before each stage and a final payment.

Consider the lump-sum scheme. From (4), the contractor's effort, $(\hat{e}_1, \hat{e}_2)$ is characterized by

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_1} - c_1'(e_1) = 0, \tag{16}$$

and

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_2} - c_2'(e_2) = 0. \tag{17}$$

Since no payments are made in the second stage, the problem is equivalent to one in which e_1 and e_2 are selected simultaneously at the beginning of the first stage.

Next consider the installment scheme. From (13), the contractor in the second stage will choose effort, $\tilde{e}_2$, characterized by

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_2} - c_2'(e_2) = 0. \tag{18}$$

Hence, in equilibrium, the contractor will adjust second-stage effort in response to (prior) changes in first-stage effort according to

$$\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2} = -\frac{\dfrac{\gamma}{\beta+\gamma}\dfrac{\partial^2 B_2}{\partial e_1 \partial e_2}}{\dfrac{\gamma}{\beta+\gamma}\dfrac{\partial^2 B_2}{\partial e_2^2} - c_2''(e_2)}. \tag{19}$$

By assumption, $\partial^2 B_2/\partial e_2^2 < 0$, and $c_2''(e_2) \geq 0$, thus

$$\text{sign}\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2} = \text{sign}\left[\frac{\partial^2 B_2}{\partial e_1 \partial e_2}\right]. \tag{20}$$

By (13), from the standpoint of stage 1, the contractor's effort, $\tilde{e}_1$, maximizes

$$\frac{\gamma}{\beta+\gamma}[B_2(e_1, e_2(e_1)) - c_2(e_2(e_1))] - c_1(e_1),$$

subject to $e_2(e_1)$ as defined by (18). Let λ be the shadow price of the constraint (18) in this maximization problem. Then the contractor's effort, $(\tilde{e}_1, \tilde{e}_2)$, is characterized by

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_1} - c_1'(e_1) - \lambda\frac{\gamma}{\beta+\gamma}\frac{\partial^2 B_2}{\partial e_1 \partial e_2} = 0, \tag{21}$$

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_2} - \frac{\gamma}{\beta+\gamma}c_2'(e_2) - \lambda\left[\frac{\gamma}{\beta+\gamma}\frac{\partial^2 B_2}{\partial e_2^2} - c_2''(e_2)\right] = 0, \tag{22}$$

and

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_2} - c_2'(e_2) = 0. \tag{18}$$

[6] This is in accordance with the work of Lambert (1983), and Fellingham, *et al.* (1985).

By eliminating λ in (21) and (22), and substituting from (18) and (19), we have

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_1} - c_1'(e_1) = -\frac{\beta}{\beta+\gamma} c_2'(e_2)\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2}. \tag{23}$$

To summarize, the effort under the installment scheme, $(\tilde{e}_1, \tilde{e}_2)$, is given by conditions (23) and (18), while the effort under the lump-sum scheme, $(\hat{e}_1, \hat{e}_2)$, is characterized by (16) and (17). Since (18) is identical to (17), the difference, if any, between the schemes will arise from the choice of the first-stage effort.

Notice that if and only if $\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2} = 0$, condition (23) simplifies to

$$\frac{\gamma}{\beta+\gamma}\frac{\partial B_2}{\partial e_1} - c_1'(e_1) = 0,$$

which is identical to (16). Now, by (19), $\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2} = 0$ if and only if $\partial^2 B_2/\partial e_1 \partial e_2 = 0$. Hence, conditions (23) and (18) are identical to (16) and (17), and consequently, the contractor's choices of effort under the two schemes are identical, $\tilde{e}_1 = \hat{e}_1$ and $\tilde{e}_2 = \hat{e}_2$, if and only if there is no intertemporal complementarity between the contractor's effort in the first stage and his effort in the second stage, $\partial^2 B_2/\partial e_1 \partial e_2 = 0$.[7]

In addition, we show in the Appendix that if there is no forward intertemporal complementarity of effort, the total profit of the buyer and contractor are identical.

Proposition 3. The installment scheme and the lump-sum scheme

(i) lead the contractor to the same choices of effort, i.e., $\hat{e}_j = \tilde{e}_j$, for $j = 1, 2$, and
(ii) provide the same total profit to the buyer and the contractor,

if and only if the marginal benefit of effort in the second stage is independent of effort in the first stage.

Proof. See Appendix.

An equivalent condition is that the buyer's benefit be additive in the effort in the two stages

$$B_2(e_1, e_2) = b_1(e_1) + b_2(e_2). \tag{24}$$

Proposition 3 implies that if the benefit is additive, then no welfare will be lost if the parties adopt a lump-sum rather than an installment scheme.

Condition (16) shows that, under the lump-sum scheme, the incentive to the contractor for effort in the first stage is the fraction $\frac{\gamma}{\beta+\gamma}$ of the marginal benefit that he will receive through the final payment. From (23) it may be seen that, under the installment scheme, the contractor has that incentive, and, *in addition,* he receives an incentive from an increment in the second installment payment.

In bargaining over the second installment, the buyer and contractor agree on a payment, $d_2 = \frac{\beta}{\beta+\gamma} c_2(\tilde{e}_2)$, that increases with the effort that the two parties expect the contractor to choose in the second stage. Since higher effort by the contractor in the first stage increases the marginal product of effort in the second stage, the contractor will choose higher effort

[7] It is straightforward to show that, in a setting of $n > 2$ stages, the contractor will choose identical effort under the two schemes if marginal benefit of effort in each stage is independent of effort in every preceding stage.

in the first stage in order to *commit* to higher effort in the second stage. He does so in the knowledge that the buyer will share in part of the cost of the higher second-stage effort through the second installment payment. In equilibrium, the contractor will choose the second-stage effort anticipated by the buyer and the contractor in bargaining over the second installment.

The installment scheme induces the contractor to choose higher effort in both stages essentially because it permits the two parties to *indirectly* condition the second installment on the effort chosen by the contractor in the second stage. As stated earlier, by giving an added reward for higher effort in the second stage, the second installment motivates greater effort in the initial stage. Understanding this, the buyer will agree to the second installment, from which both parties will gain.

This does not, however, imply that the parties should necessarily prefer the installment scheme, for it may lead the contractor to exceed the first-best level of effort. The following proposition provides a condition that ensures that the effort under the installment scheme will not overshoot the first best.

Proposition 4. The contractor's effort under the installment scheme will strictly exceed that under the lump-sum scheme, $\tilde{e}_1 > \hat{e}_1$ and $\tilde{e}_2 > \hat{e}_2$, if and only if an increase in first-stage effort leads to a strict increase in the marginal benefit of second-stage effort,

$$\frac{\partial^2 B_2}{\partial e_1 \partial e_2} > 0. \tag{25}$$

If, further,

$$c_1'(e_1) \geq c_2'(e_2)\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2}, \tag{26}$$

then the contractor's effort under the installment scheme will strictly fall short of the first-best effort, $\tilde{e}_1 < e_1^*$ and $\tilde{e}_2 < e_2^*$, and the profits of the buyer and contractor will be strictly larger under the installment scheme. Hence both parties will prefer the installment to the lump-sum scheme.

Proof. See Appendix.

With the benefit function, $B_2(e_1, e_2) = (e_1 + e_2)^{1/2}$, and stage-wise incremental costs, $c_1(e_1) = e_1^2$ and $c_2(e_2) = e_2^2$, the first-best levels of effort are

$$e_1^* = e_2^* = 0.2500,$$

the effort levels chosen by the contractor under a lump-sum scheme are

$$\hat{e}_1 = \hat{e}_2 = 0.1250,$$

and the effort levels chosen under an installment scheme are

$$\tilde{e}_1 = 0.1403, \qquad \tilde{e}_2 = 0.1299.$$

While installment payments do elicit substantially more effort from the contractor, the effort chosen still falls short of the first-best effort.

We believe that in most settings, the marginal benefit of effort in the second stage increases (weakly) with effort in the first stage. Nevertheless, we offer the following example to illustrate the effect of installment payments in the other case, where the marginal benefit of effort in the second stage *falls* with effort in the first stage. Let benefit,

$$B_2(e_1, e_2) = (e_1 + e_2)^{1/2},$$

and stage-wise incremental costs, $c_1(e_1) = e_1^2$ and $c_2(e_2) = e_2^2$. Then the first-best levels of effort are $e_1^* = e_2^* = 0.3150$, the effort levels chosen by the contractor under a lump-sum scheme are $\hat{e}_1 = \hat{e}_2 = 0.1984$, and the effort levels chosen under an installment scheme are $\tilde{e}_1 = 0.1809$, and $\tilde{e}_2 = 0.2020$. In general, when increased effort in the first stage reduces the marginal benefit of effort in the second stage, the installment scheme will lead the contractor to choose *less* effort in the first stage in order to commit to higher effort in the second stage.[8] The example indicates that, in this case, the two parties may prefer the lump-sum scheme: net benefit less cumulative costs is 0.5512 under the lump-sum scheme, as compared with 0.5453 under installment payments.

6. Implications for construction law

■ In the case of contracts for building or engineering, installment payments are ubiquitous, and are known as "interim payments." Indeed, under English law, if a contract does not explicitly rule out interim payments, they will be implied.[9] It is well established that

> Provisions for interim or progress certificates are often inserted in building contracts for the benefit of the builder, to enable him to obtain payments on account during the progress of the work. As a rule, the payments contemplated by such provisions . . . are not conclusive or binding on either party, whether as expression of satisfaction with the quality of the work or materials, . . . Such certificates, therefore, are subject to readjustment upon final certificate, . . .[10]

By rendering all payments subject to renegotiation at any stage of the project up to and including completion of the whole project, this rule safeguards the buyer against defects in the contractor's work that appear only over time. The rule, however, effectively limits the function of interim payments to financing the contractor for work in progress. This begs the question as to why it is typically the buyer, rather than a specialized financial intermediary, who provides the finance.

We have shown that renegotiation-proof installment payments redress the weakness of the contractor in *ex post* renegotiations and provide incentives for the contractor to invest greater effort. Since construction is a business subject to moral hazard and in which there are large sunk costs, our model predicts that parties to construction contracts would use renegotiation-proof installment payments to ameliorate these hazards.

Construction law in the United States derives from English law.[11] Under construction law in the United States, however, interim payments will not be implied if they are not specified. Moreover, we note that a standard construction contract developed by the American Institute of Architects states that

> The issuance of a Certificate for Payment will constitute a representation by the Architect to the Owner, based on his observations at the site . . . , that the Work has progressed to the point indicated . . . the quality of the Work is in accordance with the Contract Documents . . . [12]

This contractual provision limits the extent to which the parties may renegotiate the interim payments. The development of this provision in a standard contract to modify the common law provides some evidence in favor of our model.

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[8] This claim may be proved by an argument similar to the first step of the proof of Proposition 4.

[9] *Emden's Building Contracts and Practice,* Vol. 1, 8th Edition, p. 128.

[10] *Hudson's Building and Engineering Contracts,* 10th Edition, p. 367.

[11] See, generally, Sweet (1977).

[12] *General Conditions of the Contract for Construction,* AIA Document A201, 1976 Edition, American Institute of Architects, Washington, D.C.

7. Concluding remarks

■ In this article we have focused on contracting in situations where the performance of the contractor is subject to moral hazard, the effort invested by the contractor is completely sunk once incurred, the value to the buyer of partial work by the contractor is minimal, high costs of third-party enforcement preclude contracts contingent on the contractor's effort or the value of the product to the buyer, and vertical integration is not permissible. In these circumstances, renegotiation-proof installment payments perform two important functions: an initial (down)payment redresses the weakness of the contractor in *ex post* renegotiations, and a subsequent installment payment induces the contractor to invest greater effort.

We modelled the outcome of negotiations between a buyer and a contractor by the generalized Nash bargaining solution. We believe that any reasonable model would also predict that installment payments will share the cost that the contractor is about to sink, and that the final payment will share the benefit that the buyer is about to enjoy. It is such a scheme of sharing, together with the assumption of intertemporal complementarity, that is essential to our prediction that installment payments will induce more effort.

In reality, the degree to which the effort of the contractor in the product is sunk varies with the business: it is almost total for legal representation, custom-written software, architectural design, and construction of buildings on land owned by the buyer, but relatively lower for construction of shipping vessels. In the polar case that the contractor's cost is not sunk at all. there remains only the problem of moral hazard. The outcome of the *ex post* bargaining will then be such as to induce the contractor to invest the first-best level of effort.

If the performance of the contractor is not subject to moral hazard, and the only problem is that of the sunk costs, then a downpayment is sufficient to ameliorate the weakness of the contractor in *ex post* negotiations, and to ensure that any project that will yield gains from trade will proceed.[13]

The analysis applies directly to creative work such as the writing of software, preparation of an advertising campaign, and contract research and development, as well as to design work such as architectural and interior design: in these cases, the very employment of the professional indicates the buyer's unfamiliarity with the skills required and hence the difficulty of monitoring the effort of the contractor is so specific to the buyer that it is mostly sunk cost, and the value to the buyer of incomplete work by the contractor is minimal.

In Lambert (1983), Fellingham, et al. (1985), and Fudenberg, et al. (1987), contracts with longer duration allow payments to the contractor to be conditioned on more information, and hence generally provide higher welfare than shorter contracts. In our setting, payments may be conditioned only on the completion of stages. Whether payments are made at each stage, or only once at the beginning and once at the end, the final payment is identical because, given the contractor's effort, the bargaining positions are identical.

The payments preceding the final payment serve to share cost, and hence, depend on the effort that the parties expect the contractor to invest. By making these advance payments more frequent, the parties can indirectly condition payment on the (expected) effort of the contractor. Consequently, if higher effort by the contractor in the first stage increases the marginal product of effort in the second stage, a scheme with more frequent payments leads the contractor to invest more effort, and achieves larger gains from trade for the two parties, and hence raises welfare.

Appendix

■ The proofs of Propositions 2–4 follow.

Proof of Proposition 2. Consider negotiations at the end of the nth stage. The payment p solves the generalized Nash bargaining problem

$$\operatorname*{Max}_{p}\ [B_n - p]^{\beta} \cdot [p]^{\gamma},$$

[13] This has formally been proven by Milgrom and Roberts (1990).

and is

$$p = \frac{\gamma}{\beta + \gamma} B_n. \tag{A1}$$

Now consider negotiations at the beginning of the nth stage. The installment payment d_n solves the generalized Nash Bargaining problem

$$\underset{p}{\text{Max}}\ [B_n - p - d_n]^{\beta} \cdot [p - C_n + C_{n-1} + d_n]^{\gamma},$$

or

$$\underset{p}{\text{Max}} \left[\frac{\beta}{\beta + \gamma} B_n - d_n\right]^{\beta} \cdot \left[\frac{\gamma}{\beta + \gamma} B_n - C_n + C_{n-1} + d_n\right]^{\gamma}.$$

The solution is

$$d_n = \frac{\beta}{\beta + \gamma} c_n.$$

Consider negotiations at the beginning of any stage $j, j = 1, \ldots, n - 1$. Suppose that

$$d_i = \frac{\beta}{\beta + \gamma} c_i,$$

for $i = j + 1, \ldots, n$. Then the installment payment d_j solves the generalized Nash bargaining problem

$$\text{Max} \left[B_n - p - \sum_{i=j}^{n} d_i\right]^{\beta} \cdot \left[p + \sum_{i=j}^{n} d_i - C_n + C_{j-1}\right]^{\gamma}$$

or, by the induction hypothesis,

$$\text{Max} \left[\frac{\beta}{\beta + \gamma} B_n - \sum_{i=j+1}^{n} \frac{\beta}{\beta + \gamma} c_i - d_j\right]^{\beta} \cdot \left[\frac{\gamma}{\beta + \gamma} B_n - \sum_{i=j+1}^{n} \frac{\gamma}{\beta + \gamma} c_i + d_j - c_j\right]^{\gamma}.$$

The solution is

$$d_j = \frac{\beta}{\beta + \gamma} c_j, \tag{A2}$$

which is the result. *Q.E.D.*

Proof of Proposition 3. The first part of the proof is presented in the text immediately preceding Proposition 3. It remains to prove that the profit of the buyer and the contractor are identical. Suppose that the benefit is additive. Then, by the preceding step, $\tilde{e}_1 = \hat{e}_1$ and $\tilde{e}_2 = \hat{e}_2$, hence, by (15), the *ex ante* total payment to the contractor under the installment scheme is

$$\Pi_0^C = \frac{\gamma}{\beta + \gamma} [B_2(\tilde{e}_1, \tilde{e}_2) - C_2(\tilde{e}_1, \tilde{e}_2)] = \frac{\gamma}{\beta + \gamma} [B_2(\hat{e}_1, \hat{e}_2) - C_2(\hat{e}_1, \hat{e}_2)],$$

which, by (10), is the total payment to the contractor under the lump-sum scheme. Thus, the total payment to the buyer is identical under the two schemes. *Q.E.D.*

Proof of Proposition 4. Suppose that $\partial^2 B_2/\partial e_1 \partial e_2 > 0$. Notice that the left-hand side of (16) is the same as that of (23). From (20), $\partial^2 B_2/\partial e_1 \partial e_2 > 0$ implies that $\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2} > 0$, and hence that the right-hand side of (23) is negative. But (17) is identical to (18). Since $B_2(e_1, e_2)$ is strictly concave in (e_1, e_2), and $c_i(e_i)$, $i = 1, 2$, are weakly convex, we must have $\hat{e}_1 < \tilde{e}_1$ and $\hat{e}_2 < \tilde{e}_2$.

To prove the converse, suppose that $\hat{e}_1 < \tilde{e}_1$ and $\hat{e}_2 < \tilde{e}_2$, but $\partial^2 B_2/\partial e_1 \partial e_1 \leq 0$. Then,

$$\frac{\partial}{\partial e_2} B_2(\hat{e}_1, e_2) \geq \frac{\partial}{\partial e_2} B_2(\tilde{e}_1, e_2),$$

all e_2. By (17), the contractor's stage-two effort under the lump-sum scheme, $\hat{e}_2$, solves

$$\frac{\gamma}{\beta + \gamma} \frac{\partial}{\partial e_2} B_2(\hat{e}_1, \hat{e}_2) = c_2'(\hat{e}_2), \tag{A3}$$

hence

$$\frac{\gamma}{\beta+\gamma}\frac{\partial}{\partial e_2}B_2(\tilde{e}_1, \hat{e}_2) \le c_2'(\hat{e}_2).$$

But by (18),

$$\frac{\gamma}{\beta+\gamma}\frac{\partial}{\partial e_2}B_2(\tilde{e}_1, \tilde{e}_2) = c_2'(\tilde{e}_2). \tag{A3}$$

Since $\partial B_2/\partial e_2$ falls with e_2 and $c_2'(\cdot)$ increases with e_2, we conclude that $\tilde{e}_2 \le \hat{e}_2$, which contradicts the initial hypothesis.

From (1), the first-best effort, (e_1^*, e_2^*), is characterized by

$$\frac{\partial B_2}{\partial e_1} - c_1'(e_1) = 0, \tag{A4}$$

and

$$\frac{\partial B_2}{\partial e_2} - c_2'(e_1) = 0. \tag{A5}$$

Notice that (23) and (18) may be rewritten as

$$\frac{\partial B_2}{\partial e_1} - c_1'(e_1) = \frac{\beta}{\gamma}\left\{c_1'(e_1) - c_2'(e_2)\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2}\right\}, \tag{A6}$$

and

$$\frac{\partial B_2}{\partial e_2} - c_2'(e_2) = \frac{\beta}{\gamma}c_2'(e_2). \tag{A3'}$$

Now the left-hand sides of (A4) and (A5) correspond to those of (A6) and (A3'). If $c_1'(e_1) \ge c_2'(e_2)\left[\frac{de_2}{de_1}\right]_{\tilde{e}_2}$, the right-hand side of (A6) is nonnegative. The right-hand side of (A3) is positive. Since $B_2(e_1, e_2)$ is strictly concave in (e_1, e_2), and $c_i(e_i)$, $i = 1, 2$, are weakly convex, we must have $\tilde{e}_1 < e_1^*$ and $\tilde{e}_2 < e_2^*$.

In this case, $\hat{e}_j < \tilde{e}_j < e_j^*$, for $j = 1, 2$, hence

$$B_2(\hat{e}_1, \hat{e}_2) - C_2(\hat{e}_1, \hat{e}_2) < B_2(\tilde{e}_1, \tilde{e}_2) - C_2(\tilde{e}_1, \tilde{e}_2) < B_2(e_1^*, e_2^*) - C_2(e_1^*, e_2^*),$$

which, by (9), (10), (14), and (15), proves that the profits of both buyer and contractor are higher under the installment scheme. *Q.E.D.*

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