

SPONSOR'S PRECOMMITMENT CAPABILITY
AND ALLOCATIVE EFFICIENCY IN THE
CONSTRUCTION OF LONG TERM PROJECTS

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Working Paper Nº111

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Janeiro, 1989

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- * This paper is a revised version of part of my Ph D dissertation presented at the Department of Economics, University of Illinois at Urbana-Champaign. I would like to thank Lanny Arvan, Lawrence DeBrock and Michael Spagat for helpful comments and suggestions. The usual disclaimers apply.

ABSTRACT

We consider a repeated contract game between a sponsor and a contractor concerning a large scale project where the project requires a number of tasks to be completed before the benefit from the project can be realized. There is cost uncertainty and the contractor has private, task specific information which is relevant in cost determination. Moreover the contractor supplies effort which affects the cost of completing a task. We focus on the case where the sponsor cannot precommit to compensation per task and where the contractor is not bound to complete the project. We show that, in this case, inefficiency may arise, since the sponsor may cancel the project in instances where it would be socially optimal to fund the project. In other words, there may be real social costs when the sponsor is incapable of making a credible commitment at project initiation to the compensation schedule it will honor over the lifetime of the project.

1. INTRODUCTION

In this paper we look at a form of inefficiency in the construction of large scale, long term projects which consists in the cancellation of the project when it is socially optimal for the project to be brought to completion.

We present a dynamic contract game concerning a large scale, long term project between a single sponsor and contractor. We follow the optimal regulation literature, Baron and Myerson (1982), Baron and Besanko (1984) and (1987), Laffont and Tirole (1986), et.al., since we assume that this contract problem contains elements of both adverse selection and moral hazard. That is, we assume the contractor has some private information as to project cost which is unobservable by the sponsor and the contractor makes some decisions over the inputs it supplies in completing the project based on this private information. We also follow the optimal regulation literature in assuming that the sponsor's benefit from completion of the project is publicly known.

The formulation in the above mentioned optimal regulation papers are static and have the feature that both benefits and costs are realized simultaneously. We depart from this optimal regulation literature in our assumption that the project requires a multiplicity of tasks¹. In our model, there is a cost realization after each task has been completed, but the benefit does not accrue to the sponsor until the entire project is finished. The moral hazard in the model arises because upon completion of each task the contractor sends a signal to the sponsor as to the cost involved. This signalled cost accurately reflects the cost reducing effort provided by the contractor. However, signalled cost is but one component of the contractor's actual cost in completing the task. The contractor faces a cost from taking the effort which affects the signalled cost. This effort cost component is not observed by the sponsor since it depends on the task specific information. Moreover, the sum of the effort and signalled

¹ See Baron (1988) for a dynamic version of the optimal regulation model. The only paper we are aware of which specifically deals with procurement in a dynamic context is Lewis (1986). Lewis considers the Bayes equilibrium of a repeated contract game where the sponsor learns over time about the contractor's private information and the sponsor may cancel the project at any time if the sponsor's beliefs about this private information are sufficiently pessimistic.

cost may or may not be minimized by the contractor taking the cost reducing effort, depending on the realization of the task specific information. Since we model the sponsor as the residual claimant, the sponsor has incentive to design the contract so as to minimize the sum of the effort and signalled cost. But since the remuneration the contractor receives is a function of the signalled cost only, the sponsor must design the contract to induce self-selection on the part of the contractor.

We start by assuming that neither the sponsor nor the contractor has a precommitment capability. That is, the possibility that the contractor drops out is accompanied by the fact that the sponsor is free to alter the contractor's remuneration function after each task has been completed². We show that inefficiency may arise since the sponsor may cancel the project in instances where it would be socially optimal not to do so.

The remainder of the paper is organized as follows. In the next section we develop the basic model. In Section 3 we analyze the equilibrium of the one period game. Section 4 is devoted to an analysis of the sequential equilibrium of the dynamic contract game. In Section 5 we discuss the relationship between the sponsor's precommitment capability and allocative efficiency. Finally, we offer a brief conclusion in Section 6 where we take up the policy implications of our analysis.

2. THE BASIC SET-UP

We consider the relationship between a sponsor and a contractor over the construction of a large scale project. Assume that the project requires a prespecified number of tasks, N , for completion. For simplicity assume that each task lasts one period. Let i be an index which refers both to the number of tasks and the number of periods remaining till completion of the project; $i=1, \dots, N$. Let B denote the benefit accruing to the sponsor in the event the project is completed. It is assumed that the

² Since we assume that the sponsor can alter the remuneration function after the completion of each task, the sponsor can induce the contractor to drop out by making the remuneration sufficiently unattractive. This is the method by which the sponsor cancels the project.

benefit to the sponsor is zero in the event that the project is not completed.

At the start of period i nature makes a move. Let \tilde{t}_i denote this random variable and t_i denote the realization of this random variable. $t_i \in (\underline{c}, \bar{c})$, $\underline{c} < \bar{c}$, where $t_i = \underline{c}$ means that the i th task is low cost while $t_i = \bar{c}$ means that the i th task is high cost. We assume that \tilde{t}_h and \tilde{t}_i are statistically independent for all $h, i=1, \dots, N$, $h \neq i$. Let $P_f(\tilde{t}_i = \bar{c}) = \theta$. This probability is taken to represent the subjective beliefs of the sponsor concerning the difficulty of task i . \tilde{t}_i is observed by the contractor but not by the sponsor. However, θ is taken to be common knowledge.

The contractor's decision to complete each task is based on π , $\pi \geq 0$, the per period opportunity profit level the contractor can experience elsewhere, and the rents the contractor expects to earn from continuing to participate in the project. If the contractor has decided to complete task i the contractor then chooses the level of cost reducing effort, e_i , $e_i \in \{0, 1\}$, where $e_i = 1$ denotes that cost reducing effort has been taken and $e_i = 0$ denotes that no cost reducing effort has been taken.

The sponsor receives a perfectly informative signal of the cost reducing effort, s_i , $s_i = e_i \underline{c} + (1-e_i) \bar{c}$. We refer to s_i as the signalled cost. When $s_i = \underline{c}$ the contractor indicates to the sponsor that the task is low cost while when $s_i = \bar{c}$ the contractor indicates the task is high cost. Signalled cost is but one component of the actual cost involved in completing task i , $c^a(t_i, s_i)$. $c^a(t_i, s_i) = s_i + c^e(t_i, s_i) + c^{ad}(t_i)$, where $c^e(t_i, s_i)$ denotes the cost to the contractor from taking cost reducing effort and $c^{ad}(t_i)$ denotes the cost to the contractor due to task advantage, i.e., whether the task is low cost or high cost. The effort cost component is given by

$$\begin{aligned} c^e(t_i, \bar{c}) &= 0 && \text{for } t_i = \underline{c}, \\ c^e(\underline{c}, \underline{c}) &= \bar{c} - \underline{c} - a, \text{ and } c^e(\bar{c}, \underline{c}) > \bar{c} - \underline{c}, \end{aligned} \quad (1)$$

where a is a constant, $0 < a < \bar{c} - \underline{c}$. Thus cost reducing effort requires the expenditure of real resources and the sponsor will need to provide

incentives to the contractor to induce such effort. The task advantage term is given by

$$c^{ad}(\underline{c}) = -(\bar{c} - \underline{c} - a) \text{ and } c^{ad}(\bar{c}) = 0 \quad (2)$$

Thus the actual cost function is given by

$$\begin{aligned} c^a(\underline{c}, \underline{c}) &= \underline{c}, & c^a(\underline{c}, \bar{c}) &= \underline{c} + a, \\ c^a(\bar{c}, \underline{c}) &> \bar{c}, & \text{and} & & c^a(\bar{c}, \bar{c}) &= \bar{c}. \end{aligned} \quad (3)$$

Note that cost reducing effort is efficient, in the sense of minimizing actual costs in period i , only if task i is low cost. Also note that we have designed the actual cost function so that actual cost coincides with the signalled cost when the task is low cost, when the contractor takes cost reducing effort, and again when the task is high cost, if the contractor does not take cost reducing effort. We shall refer to this case where actual and signalled cost coincide as truthful signalling on the part of the contractor.

3. THE EQUILIBRIUM OF THE ONE PERIOD MODEL

To get the reader familiar with the underlying issues of our model, we shall first consider the special case where $N = 1$. The main ideas can be readily extended to the more general case.

Let $p_1 : (\underline{c}, \bar{c}) \rightarrow \mathbb{R}$ denote the compensation function, where $p_1(\underline{c})$ is the payment the sponsor makes to the contractor upon completion of the task when the signalled cost is \underline{c} and $p_1(\bar{c})$ is defined similarly when the signalled cost is \bar{c} . We proceed via backward induction. First, consider the cost reducing effort decision of the contractor given the prespecified compensation scheme, p_1 , and given that the contractor has chosen to complete the project. Then, $e_1 = 1$ only if

$$p_1(\underline{c}) - c^a(t_1, \underline{c}) \geq p_1(\bar{c}) - c^a(t_1, \bar{c}). \quad (4)$$

Substituting (3) into (4) when $t_1 = \underline{c}$ yields

$$p_1(\underline{c}) \geq p_1(\bar{c}) - a. \quad (5)$$

When (5) is violated the contractor has no incentive to take cost reducing effort. In the sequel we will restrict attention to the case where $p_1(\underline{c}) \leq p_1(\bar{c})$. Then (3) and (4) imply that the contractor will not take cost reducing effort when $t_1 = \bar{c}$. Moreover, we will assume that when task 1 is low cost the contractor does indeed take cost reducing effort as long as (5) is satisfied. Given these additional assumptions we shall refer to (5) as a self-selection constraint in that (5) induces truthful signalling.

Second, consider the contractor participation decision. Let q_1 , $q_1 \in \{0,1\}$, be an indicator variable such that if $q_1 = 1$ the contractor has decided to complete task 1 while if $q_1 = 0$ the contractor has decided to quit and drop out of the project. Recall that if the contractor chooses to drop out the contractor earns π . Thus, $q_1 = 1$ only if

$$\text{maximum}_{s_1} p_1(s_1) - c^a(t_1, s_1) \geq \pi \quad (6)$$

Note that when $t_1 = \bar{c}$, (6) reduces to

$$p_1(\bar{c}) \geq \bar{c} + \pi. \quad (7)$$

Substituting (7) into (5) yields

$$p_1(\underline{c}) \geq \bar{c} - a + \pi. \quad (8)$$

Evidently, if (8) holds then (6) does not bind when $s_1 = \underline{c}$. In other words, if the sponsor induces participation by the contractor with a high cost task and induces cost reducing effort by the contractor with a low cost task then the contractor with a low cost task earns a rent of at least $\bar{c} - \underline{c} - a$. The sponsor can extract this rent from the contractor with a low cost task but only by inducing the contractor with a high cost task to drop out. This is the tradeoff the sponsor contemplates in choosing the compensation scheme.

Finally, we consider the sponsor's choice of the compensation function, p_1 . We assume that the sponsor's goal is to maximize the expected net benefit, i.e., the product of the conditional expectation of the benefit minus the construction costs associated with completion of the project and the probability that the project is completed. The sponsor's problem is given by

$$\underset{p_1, q_1}{\text{maximize}} (1-\theta) q_1(\underline{c}) [B-p_1(\underline{c})] + \theta q_1(\bar{c}) [B-p_1(\bar{c})] \quad (9)$$

subject to:

$$0 \leq q_1(s_1) \leq 1, q_1(s_1) [p_1(s_1) - s_1 - \pi] \geq 0,$$

and

$$(1 - q_1(s_1)) [\pi - p_1(s_1) + s_1] \geq 0$$

for $s_1 = \underline{c}, \bar{c}$; as well as (5)³.

Note that in (9) we treat $q_1(s_1)$ as a probability rather than as an indicator variable. If at the optimum $0 < q_1(s_1) < 1$, then it must be that $p_1(s_1) - s_1 - \pi = 0$ and $B - p_1(s_1) = 0$, in which case $q_1(s_1) = 0$ or 1 is also optimal. The solution to (9) is given in the following theorem.

THEOREM 1:

Let (p_1^*, q_1^*) denote a solution to (9). Then:

$$(i) \quad p_1^*(\underline{c}) < \underline{c} + \pi, p_1^*(\bar{c}) < \underline{c} + a + \pi, \text{ and } q_1^* = 0 \text{ if } B \leq \underline{c} + \pi;$$

$$(ii) \quad p_1^*(\underline{c}) = \underline{c} + \pi, p_1^*(\bar{c}) < \underline{c} + a + \pi, q_1^*(\underline{c}) = 1,$$

$$\text{and } q_1^*(\bar{c}) = 0 \text{ if } \underline{c} + \pi \leq B \leq \bar{c} + \pi \text{ or}$$

$$\text{if } B \geq \bar{c} + \pi \text{ and } \theta \leq \frac{\bar{c} - \underline{c} - a}{B - \underline{c} - a - \pi}, \text{ and}$$

$$(iii) \quad p_1^*(\underline{c}) = \bar{c} - a + \pi, p_1^*(\bar{c}) = \bar{c} + \pi, \text{ and } q_1^* = 1 \text{ if}$$

³ In (9) we invoke the revelation principle [see Myerson (1979) or Harris and Townsend (1981)] by asserting that there is an optimal compensation function which induces truthful signalling on the part of the contractor. This is why (5) is taken as a constraint and why we have omitted t_1 as an argument of q_1 .

$$B \geq \bar{c} + \pi \text{ and } \theta \geq \frac{\bar{c} - \underline{c} - a}{B - \underline{c} - a - \pi}.$$

PROOF: See Arvan and Leite (1988).

When the sponsor doesn't know whether the task is low cost or high cost this theorem demonstrates that the tradeoff between rent extraction from the contractor with a low cost task and completion of the project from the contractor with the high cost task is resolved on the basis of the sponsor's beliefs. If the sponsor views it likely that the task will be low cost then the sponsor will opt for extracting the rent and be willing to forego the loss of surplus in the event that the task proves to be high cost. On the other hand, if the sponsor deems it likely that the task will be high cost then the risk of contractor drop-out becomes too great, in which case the compensation function rises to ensure contractor participation.

4. THE SEQUENTIAL N-PERIOD MODEL

In this section we turn to the case where $N > 1$ and solve the model via backward induction assuming that neither the sponsor nor the contractor has a precommitment capability. Furthermore, we assume that the contractor learns about the cost of each task only upon task completion. Since we restrict attention to history independent compensation schemes the condition that governs the choice of cost reducing effort is the same as in the one period game. The substantive difference between this multiperiod game and the single period game lies in the participation decision for the contractor and the compensation function decision for the sponsor. Both of these decisions are influenced by the equilibrium play in periods closer to completion of the project. That is, the expected rents to be earned influence these decisions.

We assume that the contractor is risk neutral and, hence, acts as an expected profit maximizer. Let the expected rent earned by the contractor in the equilibrium of the one period game, r_1 , be defined by

$$r_1 = (1-\theta) q_1(\underline{c}) [p_1(\underline{c}) - \underline{c} - \pi] + \theta q_1(\bar{c}) [p_1(\bar{c}) - \bar{c} - \pi] \quad (10)$$

Then, recursively define the expected rent earned by the contractor from period i till completion of the game, r_i , by

$$\begin{aligned} r_i = & (1-\theta) q_i(\underline{c}) [r_{i-1} + p_i(\underline{c}) - \underline{c} - \pi] \\ & + \theta q_i(\bar{c}) [r_{i-1} + p_i(\bar{c}) - \bar{c} - \pi], \end{aligned} \quad (11)$$

for $i = 2, \dots, N$. It follows that the contractor will continue to participate in the project in period i only if⁴

$$r_{i-1} + p_i(s_i) - s_i - \pi \geq 0. \quad (12)$$

In similar way let the expected net benefit earned by the sponsor in the equilibrium of the one period game, V_i , be defined by

$$V_i = (1-\theta) q_i(\underline{c}) [B - p_i(\underline{c})] + \theta q_i(\bar{c}) [B - p_i(\bar{c})]. \quad (13)$$

Then, recursively define the expected net benefit earned by the sponsor from period i till completion of the game, V_i , by

$$V_i = (1-\theta) q_i(\underline{c}) [V_{i-1} - p_i(\underline{c})] + \theta q_i(\bar{c}) [V_{i-1} - p_i(\bar{c})], \quad (14)$$

for $i = 2, \dots, N$. Evidently, the same reasoning as is given to prove Theorem 1 determines the optimal compensation scheme in period i . We summarize this result in the following corollary.

COROLLARY TO THEOREM 1:

Let (p_i^*, q_i^*) denote the equilibrium compensation scheme and contractor quit-stay function in period i for $i = 2, \dots, N$. Then

$$(i) \quad p_i^*(\underline{c}) < -r_{i-1} + \underline{c} + \pi, \quad p_i^*(\bar{c}) < -r_{i-1} + \underline{c} + a + \pi,$$

$$\text{and } q_i^* = 0 \text{ if } V_{i-1} \leq \underline{c} + \pi;$$

⁴ (12) is written under the assumption that truthful signalling is optimal for the contractor. We will continue to make this assumption in the remainder of the paper for ease in notation.

$$(ii) \quad p_i^*(\underline{c}) = -r_{i-1} + \underline{c} + \pi, \quad p_i^*(\bar{c}) < -r_{i-1} + \underline{c} + a + \pi,$$

$$q_i^*(\underline{c}) = 1, \text{ and } q_i^*(\bar{c}) = 0 \text{ if } \underline{c} + \pi \leq V_{i-1} \leq \bar{c} + \pi$$

$$\text{or } V_{i-1} \geq \bar{c} + \pi \text{ and } \theta \leq \frac{\bar{c} - \underline{c} - a}{V_{i-1} - \underline{c} - a - \pi + r_{i-1}},$$

and

$$(iii) \quad p_i^*(\underline{c}) = -r_{i-1} + \bar{c} - a + \pi, \quad p_i^*(\bar{c}) = -r_{i-1} + \bar{c} + \pi,$$

$$\text{and } q_i^* = 1 \text{ if } V_{i-1} \geq \bar{c} + \pi \text{ and } \theta \geq \frac{\bar{c} - \underline{c} - a}{V_{i-1} - \underline{c} - a - \pi + r_{i-1}}.$$

By substituting the results from this corollary into (11) it follows that $r_i = 0$ if either case (i) or case (ii) holds and that $r_i = (1-\theta)(\bar{c} - \underline{c} - a)$ if case (iii) holds. This limits the possible compensation schemes over time to a manageable number. Since the sponsor can always induce contractor drop-out by making the compensation function sufficiently low, it follows that $V_i \geq 0$. Then (14) implies that V_i is nonincreasing in i and is decreasing in i as long as $V_i > 0$. It follows that if case (iii) holds in period i then it necessarily holds in period $i-1$. In other words, the equilibrium contract may entail an interval near completion where the sponsor is "locked in", i.e., the project is sufficiently close to completion that the sponsor funds the project regardless of the costs. Prior to this lock-in phase the sponsor funds the project only if the task proves to be low cost and cancels if the task proves to be high cost. Of course if this initial phase is sufficiently long that the contractor believes the chance to drop-out before lock-in is sufficiently great, then the sponsor cancels the project initially rather than endure the risk of incurring substantial costs without completing the project.

This completes the presentation of the basic model. We now turn to discussing the relationship between the sponsor's precommitment capability and allocative efficiency.

5. SPONSOR'S PRECOMMITMENT CAPABILITY AND ALLOCATIVE EFFICIENCY

So far we have assumed that neither the sponsor nor the contractor had a precommitment capability. To discuss the implications that this assumption has regarding allocative efficiency, we consider instead that the sponsor is able to precommit to a given payment scheme right from the beginning of construction of the project. We still assume, however, that the contractor has no precommitment capability, i.e., that contractor drop outs can occur in any period. Rent extraction by the sponsor will never be a problem even when the sponsor is locked in right from the initiation of the project, since there is nothing to preclude the sponsor from setting up a competitive bidding among candidate contractors for the rights to the project prior to the commencement of construction as a way of extracting the rents.

Let V_i^* be the expected net social benefit from the project from period i till completion, $i = 1, \dots, N$. In the last period, productive efficiency requires that the sponsor fund the project regardless of the costs if $B \geq \bar{c} + \pi$. If $\underline{c} + \pi \leq B \leq \bar{c} + \pi$ then productive efficiency requires funding the project only if the task proves to be low cost. The project should not be funded if $B \leq \underline{c} + \pi$. Thus, we can write V_1^* as

$$V_1^* = \begin{cases} B - [\theta \bar{c} + (1-\theta) \underline{c} + \pi] & \text{if } B \geq \bar{c} + \pi \\ (1-\theta)[B - \underline{c} - \pi] & \text{if } \underline{c} + \pi \leq B \leq \bar{c} + \pi \\ 0 & \text{if } B \leq \underline{c} + \pi \end{cases} \quad (15)$$

In any other period $i > 1$, it is socially optimal to fund the project regardless of the costs in period i if $V_{i-1}^* \geq \bar{c} + \pi$. When $\underline{c} + \pi \leq V_{i-1}^* \leq \bar{c} + \pi$, it is optimal to fund the project only if the task proves to be low cost. The project should not be funded if $V_{i-1}^* \leq \underline{c} + \pi$. Thus, V_i^* is given by

$$V_i^* = \begin{cases} B-i [\theta \bar{c} + (1-\theta) \underline{c} + \pi] & \text{if } V_{i-1}^* \geq \bar{c} + \pi \\ (1-\theta) [V_{i-1}^* - \underline{c} - \pi] & \text{if } \underline{c} + \pi \leq V_{i-1}^* \leq \bar{c} + \pi \\ 0 & \text{if } V_{i-1}^* \leq \underline{c} + \pi \end{cases} \quad (16)$$

for $i = 2, \dots, N$. When the sponsor is able to precommit to the length of the project and there are no obstacles to rent extraction, in any period i the sponsor will fund the project regardless of the costs as long as $V_{i-1}^* \geq \bar{c} + \pi$, i.e., as long as it is socially optimal to do so. The equilibrium length of lock-in is then socially optimal and at least as long as in the case where the sponsor is unable of precommitting for more than one period. When the sponsor has no precommitment capability, the sponsor is "locked in" to complete the project in period i if

$$\begin{aligned} (1-\theta)(V_{i-1} - \bar{c} + a + r_{i-1} - \pi) + \theta(V_{i-1} - \bar{c} + r_{i-1} - \pi) \geq \\ (1-\theta)(V_{i-1} - \underline{c} + r_{i-1} - \pi). \end{aligned} \quad (17)$$

Since

$$(1-\theta)(V_{i-1} - \bar{c} + a + r_{i-1} - \pi) < (1-\theta)(V_{i-1} - \underline{c} + r_{i-1} - \pi)$$

then it has to be that $V_{i-1} + r_{i-1} = V_{i-1}^* > \bar{c} + \pi$ for inequality (17) to hold.

This means that if the sponsor is "locked in" to complete the project in period i when the sponsor has no precommitment ability, then the sponsor will certainly be "locked in" with i periods remaining in the event of being able to credibly commit to the entire compensation scheme. Obviously, the reverse statement is not true. This means that when the sponsor has no precommitment capability it will not always be the case that the equilibrium length of the lock-in phase is socially optimal. In fact, when the sponsor is unable to precommit and the probability that any particular task is low cost, $1-\theta$, and the cost wedge between high cost and low cost tasks, $\bar{c} - \underline{c}$, are large relative to the sponsor's net expected benefit during lock-in, it is possible that the lock-in phase will be too

short from a social welfare view. That is, the sponsor may cancel the project in instances where it would be socially optimal to fund the project.

6. CONCLUSION AND POLICY IMPLICATIONS

This work points to a form of inefficiency in the construction of large scale, long term projects which, as far as we are aware, has not received any popular attention. Since the equilibrium of our model has the property that it induces self-selection on the part of the contractor with regard to the costs the contractor announces to the sponsor, the only way that inefficiency can be manifest in our model is by completion of the project in instances where it would be socially optimal to cancel the project or by cancellation of the project when it would be socially optimal for the project to be brought to completion. It should be noted that in section 4 the sponsor is assumed incapable of precommitting to the length of the lock-in phase. Hence there is no reason to expect that the equilibrium length of the lock-in phase is socially optimal. It turns out that when the expected quasirents earned by the contractor during the lock-in phase are large relative to the net expected benefits of the sponsor during this phase, then the lock-in phase will be too short from a social welfare view. In such instances it would be beneficial for the sponsor to announce some time prior to lock-in that he/she intends to see the project to completion. These instances are more likely to occur the greater the probability that any particular task is low cost and the greater the cost wedge between high cost and low cost tasks since both of these factors contribute to the size of the quasirents. In other words, there are real social costs because the sponsor is incapable of making a credible commitment at project initiation to the compensation schedule it will honor over the lifetime of the project.

This observation provides the basis for an argument that government agencies should be guided by procurement rules concerning the cancellation decision rigid enough to ensure efficient project completion. However, in most cases, the cancellation decision appears to be left to the discretion of the project administrator. From our perspective a redefining of the project administrator's authority in such cases would be highly desirable.

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